Appendix I

List of Published Papers:

1. Jalwal, S.; Atreya, V.; **Singh, T.**; Chakraborty, S. Base Metal Catalyzed (De)Hydrogenative Formylation and Methylation Reactions Utilizing Carbon Dioxide and Methanol as C1 Sources. *Tetrahedron Letters* **2021**, *82*, 153362.

2**. Singh, T.**; Jalwal, S.; Chakraborty, S. Homogeneous First-row Transition-metal-catalyzed Carbon Dioxide Hydrogenation to Formic Acid/Formate, and Methanol. *Asian J Org Chem* **2022**, *11*, e202200330.

3. **Singh, T.**; Atreya, V.; Jalwal, S.; Anand, A.; Chakraborty, S. Advances in Group VI Metal-Catalyzed Homogeneous Hydrogenation and Dehydrogenation Reactions. *Chemistry An Asian Journal* **2023**, *18*, e202300758.

4. **Singh, T.**; Chakraborty, S. Molybdenum-Catalyzed Hydrogenation of Carbon Dioxide, Bicarbonate, and Inorganic Carbonates to Formates. *Dalton Trans.* **2024**, *53*, 10244-10249.

5. **Singh, T.**; Gutal, A.; Regina, A.; Banerjee, A.; Paranjothy, M.; Chakraborty, S. Bench-Stable Low-Valent Chromium Catalysts for Hydrogenation of CO_2, Bicarbonate, and Inorganic Carbonates to Formate. *ACS Catal.* **2024**, *14*, 14958-14965.

6. **Singh, T.**; Chakraborty S. Chromium Pincer Complexes for CO_2 and Sodium Bicarbonate Hydrogenation to Formate (Manuscript submitted).

7. **Singh, T.**; Chakraborty S. Chromium Complexes for CO_2 Transfer Hydrogenation using Isopropanol Under Ambient Conditions (Under revision in Catalysis Science & Technology).

8. **Singh, T.**; Yadav V.; Bhattachrayya, S., Chakraborty, S. NIR II Emissive Cr(0) Complex: Synthesis, Structure, TD-DFT and Bioactivity. (Manuscript to be submitted).

...

References

(1) *Applied Homogeneous Catalysis with Organometallic Compounds*, 1st ed.; Cornils, B., Herrmann, W. A., Eds.; Wiley, **2002**.
(2) Bhaduri, S.; Mukesh, D. *Homogeneous Catalysis: Mechanisms and Industrial Applications*, 1st ed.; Wiley, **2014**.
(3) Trost, B. M. Atom Economy—A Challenge for Organic Synthesis: Homogeneous Catalysis Leads the Way. *Angew. Chem. Int. Ed. Engl.* **1995**, *34*, 259–281.
(4) Sodhi, R. K. Metal Complexes in Medicine: An Overview and Update from Drug Design Perspective. *CTOIJ* **2019**, *14*.
(5) Jessop, P. G.; Joó, F.; Tai, C.-C. Recent Advances in the Homogeneous Hydrogenation of Carbon Dioxide. *Coordination Chemistry Reviews* **2004**, *248*, 2425–2442.
(6) Frei, A.; Zuegg, J.; Elliott, A. G.; Baker, M.; Braese, S.; Brown, C.; Chen, F.; G. Dowson, C.; Dujardin, G.; Jung, N.; King, A. P.; Mansour, A. M.; Massi, M.; Moat, J.; Mohamed, H. A.; Renfrew, A. K.; Rutledge, P. J.; Sadler, P. J.; Todd, M. H.; Willans, C. E.; Wilson, J. J.; Cooper, M. A.; Blaskovich, M. A. T. Metal Complexes as a Promising Source for New Antibiotics. *Chem. Sci.* **2020**, *11*, 2627–2639.
(7) Wang, W.-H.; Hime, Y. Recent Advances in Transition Metal-Catalysed Homogeneous Hydrogenation of Carbon Dioxide in Aqueous Media. In *Hydrogenation*; Karam, I., Ed.; InTech, 2012.
(8) Frei, A. Metal Complexes, an Untapped Source of Antibiotic Potential? *Antibiotics* **2020**, *9*, 90.
(9) Li, F.; Collins, J. G.; Keene, F. R. Ruthenium Complexes as Antimicrobial Agents. *Chem. Soc. Rev.* **2015**, *44*, 2529–2542.
(10) Johnson, N. B.; Lennon, I. C.; Moran, P. H.; Ramsden, J. A. Industrial-Scale Synthesis and Applications of Asymmetric Hydrogenation Catalysts. *Acc. Chem. Res.* **2007**, *40*, 1291–1299.
(11) *Catalysis without Precious Metals*, 1st ed.; Bullock, R. M., Ed.; Wiley, **2010**.
(12) Bullock, R. M. Abundant Metals Give Precious Hydrogenation Performance. *Science* **2013**, *342*, 1054–1055.
(13) Spivey, J. J. Catalysis in the Development of Clean Energy Technologies. *Catalysis Today* **2005**, *100*, 171–180.
(14) Ritchie, H.; Roser, M. Fossil Fuels. *Our World in Data.* **2020**.
(15) Hansen, J.; Sato, M. Greenhouse Gas Growth Rates. *Proc. Natl. Acad. Sci. U.S.A.* **2004**, *10*, 16109–16114.
(16) Schneider, S. H. The Greenhouse Effect: Science and Policy. *Science* **1989**, *24*, 771–781.
(17) Mauna Loa Observatory, Hawaii; https://www.co2.earth/ (Accessed June 2022).
(18) Diffenbaugh, N. S.; Singh, D.; Mankin, J. S.; Horton, D. E.; Swain, D. L.; Touma, D.; Charland, A.; Liu, Y.; Haugen, M.; Tsiang, M.; Rajaratnam, B. Quantifying the Influence of Global Warming on Unprecedented Extreme Climate Events. *Proc. Natl. Acad. Sci. U.S.A.* **2017**, *114*, 4881–4886.
(19) Senftle, T. P.; Carter, E. A. The Holy Grail: Chemistry Enabling an Economically Viable CO_2 Capture, Utilization, and Storage Strategy. *Acc. Chem. Res.* **2017**, *50*, 472–475.
(20) Song, C. Global Challenges and Strategies for Control, Conversion and Utilization of CO_2 for Sustainable Development Involving Energy, Catalysis, Adsorption and Chemical Processing. *Catalysis Today* **2006**, *115*, 2–32
(21) Von Der Assen, N.; Jung, J.; Bardow, A. Life-Cycle Assessment of Carbon Dioxide Capture and Utilization: Avoiding the Pitfalls. *Energy Environ. Sci.* **2013**, *6*, 2721.
(22) Mac Dowell, N.; Fennell, P. S.; Shah, N.; Maitland, G. C. The Role of CO2 Capture and Utilization in Mitigating Climate Change. *Nature Clim Change* **2017**, *7*, 243–249.
(23) *Aresta, M.; Carbon Dioxide as Chemical Feedstock; Wiley-VCH: Weinheim, Germany,* ***2010****.*

(24) Keijer, T.; Bakker, V.; Slootweg, J. C. Circular chemistry to enable a circular economy. *Nat. Chem* **2019**, *11*, 190-195.
(25) Circular Economy. The Ellen MacArthur Foundation. https:// www.ellenmacarthurfoundation.org/circular-economy/concept.
(26) Behr, A.; Vorholt, A. J. Introduction. In *Homogeneous Catalysis with Renewables*; Catalysis by Metal Complexes; Springer International Publishing: Cham, **2017**; Vol. 39, pp 1–19.
(27) Peters, M.; Köhler, B.; Kuckshinrichs, W.; Leitner, W.; Markewitz, P.; Müller, T. E. Chemical Technologies for Exploiting and Recycling Carbon Dioxide into the Value Chain. *ChemSusChem* **2011**, *4* (9), 1216–1240.
(28) Cokoja, M.; Bruckmeier, C.; Rieger, B.; Herrmann, W. A.; Kühn, F. E. Transformation of Carbon Dioxide with Homogeneous Transition-Metal Catalysts: A Molecular Solution to a Global Challenge? *Angew. Chem. Int. Ed.* **2011**, *50*, 8510–8537.
(29) Leitner, W. Carbon Dioxide as a Raw Material: The Synthesis of Formic Acid and Its Derivatives from CO_2. *Angew. Chem. Int. Ed. Engl.* **1995**, *34*, 2207–2221.
(30) Sakakura, T.; Choi, J.-C.; Yasuda, H. Transformation of Carbon Dioxide. *Chem. Rev.* **2007**, *107*, 2365–2387.
(31) Omae, I. Recent Developments in Carbon Dioxide Utilization for the Production of Organic Chemicals. *Coord. Chem. Rev.* **2012**, *256*, 1384–1405.
(32) Liu, Q.; Wu, L.; Jackstell, R.; Beller, M. Using Carbon Dioxide as a Building Block in Organic Synthesis. *Nat. Commun.* **2015**, *6*, 5933.
(33) Huang, K.; Sun, C.-L.; Shi, Z.-J. Transition-Metal-Catalyzed C–C Bond Formation through the Fixation of Carbon Dioxide. *Chem. Soc. Rev.* **2011**, *40*, 2435.
(34) Olah, G. A.; Prakash, G. K. S.; Goeppert, A. Anthropogenic Chemical Carbon Cycle for a Sustainable Future. *J. Am. Chem. Soc.* **2011**, *133*, 12881–12898.
(35) Aresta, M.; Dibenedetto, A.; Angelini, A. Catalysis for the Valorization of Exhaust Carbon: From CO_2 to Chemicals, Materials, and Fuels. Technological Use of CO_2. *Chem. Rev.* **2014**, *114*, 1709–1742.
(36) Enthaler, S. Carbon Dioxide—The Hydrogen-Storage Material of the Future? *ChemSusChem* **2008**, *1*, 801–804.
(37) Wu L.; Liu Q.; Jackstell R.; Beller M. in Carbon Dioxide and Organometallics, *Springer International Publishing*, **2015**, 279-304.
(38) Jessop, P. G.; Ikariya, T.; Noyori, R. Homogeneous Hydrogenation of Carbon Dioxide. *Chem. Rev.* **1995**, *95*, 259-272.
(39) Jessop, P. G.; Joó, F.; Tai, C.-C. Recent advances in the homogeneous hydrogenation of carbon dioxide. *Coord. Chem. Rev.* **2004**, *248*, 2425-2442.
(40) Chong, C. C.; Kinjo, R. Catalytic Hydroboration of Carbonyl Derivatives, Imines, and Carbon Dioxide. *ACS Catal.* **2015**, *5*, 3238–3259.
(41) Bontemps, S. Boron-Mediated Activation of Carbon Dioxide. *Coordination Chemistry Reviews* **2016**, *308*, 117–130.
(42) Zhang, Y.; Zhang, T.; Das, S. Catalytic Transformation of CO_2 into C1 Chemicals Using Hydrosilanes as a Reducing Agent. *Green Chem.* **2020**, *22*, 1800–1820
(43) Lewis, N. S.; Nocera, D. G. Powering the Planet: Chemical Challenges in Solar Energy Utilization. *Proc. Natl. Acad. Sci. U.S.A.* **2006**, *103*, 15729–15735.
(44) Dalebrook, A. F.; Gan, W.; Grasemann, M.; Moret, S.; Laurenczy, G. Hydrogen Storage: Beyond Conventional Methods. *Chem. Commun.* **2013**, *49*, 8735.
(45) Fijita, J.; Wesselbaum, S.; Beydoun, K.; Leitner, W. Selective Catalytic Synthesis Using the Combination of Carbon Dioxide and Hydrogen: Catalytic Chess at the Interface of Energy and Chemistry. *Angew. Chem. Int. Ed.* **2016**, *55*, 7296–7343.
(46) Bai, S.-T.; De Smet, G.; Liao, Y.; Sun, R.; Zhou, C.; Beller, M.; Maes, B. U. W.; Sels, B. F. Homogeneous and Heterogeneous Catalysts for Hydrogenation of CO_2 to Methanol under Mild Conditions. *Chem. Soc. Rev.* **2021**, *50*, 4259–4298.
(47) Álvarez, A.; Bansode, A.; Urakawa, A.; Bavykina, A. V.; Wezendonk, T. A.; Makkee, M.; Gascon, J.; Kapteijn, F. Challenges in the Greener Production of Formates/Formic Acid,

Methanol, and DME by Heterogeneously Catalyzed CO_2 Hydrogenation Processes. *Chem. Rev.* **2017**, *117*, 9804–9838.
(48) Jiang, X.; Nie, X.; Guo, X.; Song, C.; Chen, J. G. Recent Advances in Carbon Dioxide Hydrogenation to Methanol via Heterogeneous Catalysis. *Chem. Rev.* **2020**, *120*, 7984–8034.
(49) Wang, W.; Wang, S.; Ma, X.; Gong, J. Recent Advances in Catalytic Hydrogenation of Carbon Dioxide. *Chem. Soc. Rev.* **2011**, *40*, 3703.
(50) Chirik, P.; Morris, R. Getting Down to Earth: The Renaissance of Catalysis with Abundant Metals. *Acc. Chem. Res.* **2015**, *48*, 2495–2495.
(51) Irrgang, T.; Kempe, R. 3d-Metal Catalyzed N- and C-Alkylation Reactions via Borrowing Hydrogen or Hydrogen Autotransfer. *Chem. Rev.* **2019**, *119*, 2524–2549.
(52) Albrecht, M.; Bedford, R.; Plietker, B. Catalytic and Organometallic Chemistry of Earth-Abundant Metals. *Organometallics* **2014**, *33*, 5619–5621.
(53) Alig, L.; Fritz, M.; Schneider, S. First-Row Transition Metal (De)Hydrogenation Catalysis Based On Functional Pincer Ligands. *Chem. Rev.* **2019**, *119*, 2681–2751.
(54) Elsby, M. R.; Baker, R. T. Strategies and Mechanisms of Metal–Ligand Cooperativity in First-Row Transition Metal Complex Catalysts. *Chem. Soc. Rev.* **2020**, *49*, 8933–8987.
(55) Liu, W.; Sahoo, B.; Junge, K.; Beller, M. Cobalt Complexes as an Emerging Class of Catalysts for Homogeneous Hydrogenations. *Acc. Chem. Res.* **2018**, *51*, 1858–1869.
(56) Filonenko, G. A.; Van Putten, R.; Hensen, E. J. M.; Pidko, E. A. Catalytic (de)Hydrogenation Promoted by Non-Precious Metals – Co, Fe and Mn: Recent Advances in an Emerging Field. *Chem. Soc. Rev.* **2018**, *47*, 1459–1483.
(57) Mukherjee, A.; Milstein, D. Homogeneous Catalysis by Cobalt and Manganese Pincer Complexes. *ACS Catal.* **2018**, *8*, 11435–11469.
(58) Gonsalvi, L.; Guerriero, A.; Kostera, S. Homogeneously Catalyzed CO_2 Hydrogenation to Formic Acid/Formate with Non-precious Metal Catalysts. In *CO2 Hydrogenation Catalysis*; Himeda, Y., Ed.; Wiley, 2021; pp 53–88.
(59) Bernskoetter, W. H.; Hazari, N. Reversible Hydrogenation of Carbon Dioxide to Formic Acid and Methanol: Lewis Acid Enhancement of Base Metal Catalysts. *Acc. Chem. Res.* **2017**, *50*, 1049–1058.
(60) Jalwal, S.; Atreya, V.; Singh, T.; Chakraborty, S. Base Metal Catalyzed (De)Hydrogenative Formylation and Methylation Reactions Utilizing Carbon Dioxide and Methanol as C1 Sources. *Tetrahedron Letters* **2021**, *82*, 153362.
(61) Olah, G. A.; Goeppert, A.; Prakash, G. K. S. *Beyond Oil and Gas: The Methanol Economy*, 1st ed.; Wiley, 2009.
(62) Enthaler, S.; Von Langermann, J.; Schmidt, T. Carbon Dioxide and Formic Acid—the Couple for Environmental-Friendly Hydrogen Storage? *Energy Environ. Sci.* **2010**, *3*, 1207.
(63) Grasemann, M.; Laurenczy, G. Formic Acid as a Hydrogen Source – Recent Developments and Future Trends. *Energy Environ. Sci.* **2012**, *5*, 8171.
(64) Hietala, J.; Vuori, A.; Johnsson, P.; Pollari, I.; Reutemann, W.; Kieczka, H. Formic Acid. In *Ullmann's Encyclopedia of Industrial Chemistry*; Wiley-VCH, Ed.; Wiley, 2016; pp 1–22.
(65) Jiang, H.; Singh, S. K.; Yan, J.; Zhang, X.; Xu, Q. Liquid-Phase Chemical Hydrogen Storage: Catalytic Hydrogen Generation under Ambient Conditions. *ChemSusChem* **2010**, *3*, 541–549.
(66) Singh, A. K.; Singh, S.; Kumar, A. Hydrogen Energy Future with Formic Acid: A Renewable Chemical Hydrogen Storage System. *Catal. Sci. Technol.* **2016**, *6*, 12–40.
(67) Mellmann, D.; Sponholz, P.; Junge, H.; Beller, M. Formic Acid as a Hydrogen Storage Material – Development of Homogeneous Catalysts for Selective Hydrogen Release. *Chem. Soc. Rev.* **2016**, *45*, 3954–3988.
(68) Loges, B.; Boddien, A.; Gärtner, F.; Junge, H.; Beller, M. Catalytic Generation of Hydrogen from Formic Acid and Its Derivatives: Useful Hydrogen Storage Materials. *Top Catal* **2010**, *53*, 902–914.
(69) Yu, X.; Pickup, P. G. Recent Advances in Direct Formic Acid Fuel Cells (DFAFC). *Journal of Power Sources* **2008**, *182*, 124–132.
(70) Eppinger, J.; Huang, K.-W. Formic Acid as a Hydrogen Energy Carrier. *ACS Energy Lett.* **2017**, *2*, 188–195.

(71) Chen, X.; Liu, Y.; Wu, J. Sustainable Production of Formic Acid from Biomass and Carbon Dioxide. *Molecular Catalysis* **2020**, *483*, 110716.
(72) Tsai, J. C.; Nicholas, K. M. Rhodium-Catalyzed Hydrogenation of Carbon Dioxide to Formic Acid. *J. Am. Chem. Soc.* **1992**, *114*, 5117–5124.
(73) Hayashi, H.; Ogo, S.; Fukuzumi, S. Aqueous Hydrogenation of Carbon Dioxide Catalysed by Water-Soluble Ruthenium Aqua Complexes under Acidic Conditions. *Chem. Commun.* **2004**, No. 23, 2714.
(74) Ogo, S.; Kabe, R.; Hayashi, H.; Harada, R.; Fukuzumi, S. Mechanistic Investigation of CO2 Hydrogenation by Ru(II) and Ir(III) Aqua Complexes under Acidic Conditions: Two Catalytic Systems Differing in the Nature of the Rate Determining Step. *Dalton Trans.* **2006**, No. 39, 4657.
(75) Rohmann, K.; Kothe, J.; Haenel, M. W.; Englert, U.; Hölscher, M.; Leitner, W. Hydrogenation of CO_2 to Formic Acid with a Highly Active Ruthenium Acriphos Complex in DMSO and DMSO/Water. *Angew Chem Int Ed* **2016**, *55*, 8966–8969.
(76) Leitner, W.; Dinjus, E.; Gaßner, F. Activation of Carbon Dioxide. *Journal of Organometallic Chemistry* **1994**, *475*, 257–266.
(77) Jessop, P. G.; Ikariya, T.; Noyori, R. Homogeneous Catalytic Hydrogenation of Supercritical Carbon Dioxide. *Nature* **1994**, *368*, 231–233.
(78) Qadir, M. I.; Weilhard, A.; Fernandes, J. A.; De Pedro, I.; Vieira, B. J. C.; Waerenborgh, J. C.; Dupont, J. Selective Carbon Dioxide Hydrogenation Driven by Ferromagnetic RuFe Nanoparticles in Ionic Liquids. *ACS Catal.* **2018**, *8*, 1621–1627.
(79) Farlow, M. W.; Adkins, H. The Hydrogenation of Carbon Dioxide and a Correction of the Reported Synthesis of Urethans. *J. Am. Chem. Soc.* **1935**, *57*, 2222–2223.
(80) Bulushev, D. A.; Ross, J. R. H. Towards Sustainable Production of Formic Acid. *ChemSusChem* **2018**, *11*, 821–836.
(81) Inoue, Y.; Izumida, H.; Sasaki, Y.; Hashimoto, H. CATALYTIC FIXATION OF CARBON DIOXIDE TO FORMIC ACID BY TRANSITION-METAL COMPLEXES UNDER MILD CONDITIONS. *Chem. Lett.* **1976**, *5*, 863–864.
(82) Behr, A.; Nowakowski, K. Catalytic Hydrogenation of Carbon Dioxide to Formic Acid. In *Advances in Inorganic Chemistry*; Elsevier, 2014; Vol. 66, pp 223–258.
(83) Wang, W.-H.; Hime, Y. Recent Advances in Transition Metal-Catalysed Homogeneous Hydrogenation of Carbon Dioxide in Aqueous Media. In *Hydrogenation*; Karam, I., Ed.; InTech, 2012.
(84) Evans, G. O.; Newell, C. J. Conversion of CO_2, H_2, and Alcohols into Formate Esters Using Anionic Iron Carbonyl Hydrides. *Inorganica Chimica Acta* **1978**, *31*, L387–L389.
(85) Tai, C.-C.; Chang, T.; Roller, B.; Jessop, P. G. High-Pressure Combinatorial Screening of Homogeneous Catalysts: Hydrogenation of Carbon Dioxide. *Inorg. Chem.* **2003**, *42*, 7340–7341.
(86) Federsel, C.; Boddien, A.; Jackstell, R.; Jennerjahn, R.; Dyson, P. J.; Scopelliti, R.; Laurenczy, G.; Beller, M. A Well-Defined Iron Catalyst for the Reduction of Bicarbonates and Carbon Dioxide to Formates, Alkyl Formates, and Formamides. *Angew. Chem. Int. Ed.* **2010**, *49*, 9777–9780.
(87) Langer, R.; Diskin-Posner, Y.; Leitus, G.; Shimon, L. J. W.; Ben-David, Y.; Milstein, D. Low-Pressure Hydrogenation of Carbon Dioxide Catalyzed by an Iron Pincer Complex Exhibiting Noble Metal Activity. *Angew. Chem. Int. Ed.* **2011**, *50*, 9948–9952.
(88) Ziebart, C.; Federsel, C.; Anbarasan, P.; Jackstell, R.; Baumann, W.; Spannenberg, A.; Beller, M. Well-Defined Iron Catalyst for Improved Hydrogenation of Carbon Dioxide and Bicarbonate. *J. Am. Chem. Soc.* **2012**, *134*, 20701–20704.
(89) Zhu, F.; Zhu-Ge, L.; Yang, G.; Zhou, S. Iron-Catalyzed Hydrogenation of Bicarbonates and Carbon Dioxide to Formates. *ChemSusChem* **2015**, *8*, 609–612..
(90) Rivada-Wheelaghan, O.; Dauth, A.; Leitus, G.; Diskin-Posner, Y.; Milstein, D. Synthesis and Reactivity of Iron Complexes with a New Pyrazine-Based Pincer Ligand, and Application in Catalytic Low-Pressure Hydrogenation of Carbon Dioxide. *Inorg. Chem.* **2015**, *54*, 4526–4538.
(91) Fong, H.; Peters, J. C. Hydricity of an Fe–H Species and Catalytic CO_2 Hydrogenation. *Inorg. Chem.* **2015**, *54*, 5124–5135.

(92) Bertini, F.; Mellone, I.; Ienco, A.; Peruzzini, M.; Gonsalvi, L. Iron(II) Complexes of the Linear *Rac*- Tetraphos-1 Ligand as Efficient Homogeneous Catalysts for Sodium Bicarbonate Hydrogenation and Formic Acid Dehydrogenation. *ACS Catal.* **2015**, *5*, 1254–1265.
(93) Thai, T.; Mérel, D. S.; Poater, A.; Gaillard, S.; Renaud, J. Highly Active Phosphine-Free Bifunctional Iron Complex for Hydrogenation of Bicarbonate and Reductive Amination. *Chemistry A European J* **2015**, *21*, 7066–7070.
(94) Coufourier, S.; Gaignard Gaillard, Q.; Lohier, J.-F.; Poater, A.; Gaillard, S.; Renaud, J.-L. Hydrogenation of CO_2, Hydrogenocarbonate, and Carbonate to Formate in Water Using Phosphine Free Bifunctional Iron Complexes. *ACS Catal.* **2020**, *10*, 2108–2116.
(95) Zhang, Y.; MacIntosh, A. D.; Wong, J. L.; Bielinski, E. A.; Williard, P. G.; Mercado, B. Q.; Hazari, N.; Bernskoetter, W. H. Iron Catalyzed CO_2 Hydrogenation to Formate Enhanced by Lewis Acid Co-Catalysts. *Chem. Sci.* **2015**, *6*, 4291–4299.
(96) Bertini, F.; Gorgas, N.; Stöger, B.; Peruzzini, M.; Veiros, L. F.; Kirchner, K.; Gonsalvi, L. Efficient and Mild Carbon Dioxide Hydrogenation to Formate Catalyzed by Fe(II) Hydrido Carbonyl Complexes Bearing 2,6-(Diaminopyridyl)Diphosphine Pincer Ligands. *ACS Catal.* **2016**, *6*, 2889–2893.
(97) Kothandaraman, J.; Goeppert, A.; Czaun, M.; Olah, G. A.; Surya Prakash, G. K. CO_2 Capture by Amines in Aqueous Media and Its Subsequent Conversion to Formate with Reusable Ruthenium and Iron Catalysts. *Green Chem.* **2016**, *18*, 5831–5838.
(98) Kar, S.; Goeppert, A.; Galvan, V.; Chowdhury, R.; Olah, J.; Prakash, G. K. S. A Carbon-Neutral CO_2 Capture, Conversion, and Utilization Cycle with Low-Temperature Regeneration of Sodium Hydroxide. *J. Am. Chem. Soc.* **2018**, *140*, 16873–16876.
(99) Smith, N. E.; Bernskoetter, W. H.; Hazari, N.; Mercado, B. Q. Synthesis and Catalytic Activity of PNP-Supported Iron Complexes with Ancillary Isonitrile Ligands. *Organometallics* **2017**, *36*, 3995–4004.
(100) Coufourier, S.; Gaillard, S.; Clet, G.; Serre, C.; Daturi, M.; Renaud, J.-L. A MOF-Assisted Phosphine Free Bifunctional Iron Complex for the Hydrogenation of Carbon Dioxide, Sodium Bicarbonate and Carbonate to Formate. *Chem. Commun.* **2019**, *55*, 4977–4980.
(101) Federsel, C.; Ziebart, C.; Jackstell, R.; Baumann, W.; Beller, M. Catalytic Hydrogenation of Carbon Dioxide and Bicarbonates with a Well-Defined Cobalt Dihydrogen Complex. *Chem. Eur. J.* **2012**, *18*, 72–75.
(102) Jeletic, M. S.; Mock, M. T.; Appel, A. M.; Linehan, J. C. A Cobalt-Based Catalyst for the Hydrogenation of CO_2 under Ambient Conditions. *J. Am. Chem. Soc.* **2013**, *135*, 11533–11536.
(103) Jeletic, M. S.; Helm, M. L.; Hulley, E. B.; Mock, M. T.; Appel, A. M.; Linehan, J. C. A Cobalt Hydride Catalyst for the Hydrogenation of CO_2: Pathways for Catalysis and Deactivation. *ACS Catal.* **2014**, *4*, 3755–3762.
(104) Badiei, Y. M.; Wang, W.-H.; Hull, J. F.; Szalda, D. J.; Muckerman, J. T.; Himeda, Y.; Fujita, E. Cp*Co(III) Catalysts with Proton-Responsive Ligands for Carbon Dioxide Hydrogenation in Aqueous Media. *Inorg. Chem.* **2013**, *52*, 12576–12586.
(105) Spentzos, A. Z.; Barnes, C. L.; Bernskoetter, W. H. Effective Pincer Cobalt Precatalysts for Lewis Acid Assisted CO_2 Hydrogenation. *Inorg. Chem.* **2016**, *55*, 8225–8233.
(106) Burgess, S. A.; Grubel, K.; Appel, A. M.; Wiedner, E. S.; Linehan, J. C. Hydrogenation of CO_2 at Room Temperature and Low Pressure with a Cobalt Tetraphosphine Catalyst. *Inorg. Chem.* **2017**, *56*, 8580–8589.
(107) Vollmer, M. V.; Ye, J.; Linehan, J. C.; Graziano, B. J.; Preston, A.; Wiedner, E. S.; Lu, C. C. Cobalt-Group 13 Complexes Catalyze CO_2 Hydrogenation via a Co(−I)/Co(I) Redox Cycle. *ACS Catal.* **2020**, *10*, 2459–2470.
(108) Choi, J.; Lee, Y. Catalytic Hydrogenation of CO_2 at a Structurally Rigidified Cobalt Center. *Inorg. Chem. Front.* **2020**, *7*, 1845–1850.
(109) Inoue, Y.; Izumida, H.; Sasaki, Y.; Hashimoto, H. CATALYTIC FIXATION OF CARBON DIOXIDE TO FORMIC ACID BY TRANSITION-METAL COMPLEXES UNDER MILD CONDITIONS. *Chem. Lett.* **1976**, *5*, 863–864.

(110) Enthaler, S.; Brück, A.; Kammer, A.; Junge, H.; Irran, E.; Gülak, S. Exploring the Reactivity of Nickel Pincer Complexes in the Decomposition of Formic Acid to CO_2 /H_2 and the Hydrogenation of $NaHCO_3$ to HCOONa. *ChemCatChem* **2015**, *7*, 65–69.
(111) Burgess, S. A.; Kendall, A. J.; Tyler, D. R.; Linehan, J. C.; Appel, A. M. Hydrogenation of CO_2 in Water Using a Bis(Diphosphine) Ni–H Complex. *ACS Catal.* **2017**, *7*, 3089–3096.
(112) Schieweck, R. C.; Vollmer, M. V.; Xie, J.; Ye, J.; Linehan, J. C.; Burgess, S. A.; Appel, A. M.; Gagliardi, L.; Lu, C. C. A Bimetallic Nickel–Gallium Complex Catalyzes CO_2 Hydrogenation via the Intermediacy of an Anionic d^{10} Nickel Hydride. *J. Am. Chem. Soc.* **2017**, *139*, 14244–14250.
(113) Schieweck, B. G.; Westhues, N. F.; Klankermayer, J. A Highly Active Non-Precious Transition Metal Catalyst for the Hydrogenation of Carbon Dioxide to Formates. *Chem. Sci.* **2019**, *10*, 6519–6523.
(114) Sivanesan, D.; Seo, B.; Lim, C.-S.; Kim, H.-G. Facile Hydrogenation of Bicarbonate to Formate in Aqueous Medium by Highly Stable Nickel-Azatrane Complex. *Journal of Catalysis* **2020**, *382*, 121–128.
(115) Watari, R.; Kayaki, Y.; Hirano, S.; Matsumoto, N.; Ikariya, T. Hydrogenation of Carbon Dioxide to Formate Catalyzed by a Copper/1,8-Diazabicyclo[5.4.0]Undec-7-ene System. *Adv Synth Catal* **2015**, *357*, 1369–1373.
(116) Zall, C. M.; Linehan, J. C.; Appel, A. M. A Molecular Copper Catalyst for Hydrogenation of CO_2 to Formate. *ACS Catal.* **2015**, *5*, 5301–5305.
(117) Zall, C. M.; Linehan, J. C.; Appel, A. M. Triphosphine-Ligated Copper Hydrides for CO_2 Hydrogenation: Structure, Reactivity, and Thermodynamic Studies. *J. Am. Chem. Soc.* **2016**, *138*, 9968–9977.
(118) Romero, E. A.; Zhao, T.; Nakano, R.; Hu, X.; Wu, Y.; Jazzar, R.; Bertrand, G. Tandem Copper Hydride–Lewis Pair Catalysed Reduction of Carbon Dioxide into Formate with Dihydrogen. *Nat Catal* **2018**, *1*, 743–747.
(119) Chaudhary, K.; Trivedi, M.; Masram, D. T.; Kumar, A.; Kumar, G.; Husain, A.; Rath, N. P. A Highly Active Copper Catalyst for the Hydrogenation of Carbon Dioxide to Formate under Ambient Conditions. *Dalton Trans.* **2020**, *49*, 2994–3000.
(120) Trivedi, M.; Kumar, A.; Husain, A.; Rath, N. P. Copper(I) Complexes Containing PCP Ligand Catalyzed Hydrogenation of Carbon Dioxide to Formate under Ambient Conditions. *Inorg. Chem.* **2021**, *60*, 4385–4396.
(121) Dubey, A.; Nencini, L.; Fayzullin, R. R.; Nervi, C.; Khusnutdinova, J. R. Bio-Inspired Mn(I) Complexes for the Hydrogenation of CO_2 to Formate and Formamide. *ACS Catal.* **2017**, *7*, 3864–3868.
(122) Bertini, F.; Glatz, M.; Gorgas, N.; Stöger, B.; Peruzzini, M.; Veiros, L. F.; Kirchner, K.; Gonsalvi, L. Carbon Dioxide Hydrogenation Catalysed by Well-Defined Mn(I) PNP Pincer Hydride Complexes. *Chem. Sci.* **2017**, *8*, 5024–5029.
(123) Kumar, A.; Daw, P.; Espinosa-Jalapa, N. A.; Leitus, G.; Shimon, L. J. W.; Ben-David, Y.; Milstein, D. CO_2 Activation by Manganese Pincer Complexes through Different Modes of Metal–Ligand Cooperation. *Dalton Trans.* **2019**, *48*, 14580–14584.
(124) Kostera, S.; Weber, S.; Peruzzini, M.; Veiros, L. F.; Kirchner, K.; Gonsalvi, L. Carbon Dioxide Hydrogenation to Formate Catalyzed by a Bench-Stable, Non-Pincer-Type Mn(I) Alkylcarbonyl Complex. *Organometallics* **2021**, *40*, 1213–1220.
(125) Schlenker, K.; Christensen, E. G.; Zhanserkeev, A. A.; McDonald, G. R.; Yang, E. L.; Lutz, K. T.; Steele, R. P.; VanderLinden, R. T.; Saouma, C. T. Role of Ligand-Bound CO_2 in the Hydrogenation of CO_2 to Formate with a (PNP)Mn Catalyst. *ACS Catal.* **2021**, *11*, 8358–8369.
(126) Wei, D.; Sang, R.; Sponholz, P.; Junge, H.; Beller, M. Reversible Hydrogenation of Carbon Dioxide to Formic Acid Using a Mn-Pincer Complex in the Presence of Lysine. *Nat Energy* **2022**, *7*, 438–447.
(127) Darensbourg, D. J.; Rokicki, A.; Darensbourg, M. Y. Facile Reduction of Carbon Dioxide by Anionic Group 6b Metal Hydrides. Chemistry Relevant to Catalysis of the Water-Gas Shift Reaction. *J. Am. Chem. Soc.* **1981**, *103*, 3223–3224.

(128) Darensbourg, D. J.; Ovalles, C. Anionic Group 6B Metal Carbonyls as Homogeneous Catalysts for Carbon Dioxide/Hydrogen Activation. The Production of Alkyl Formates. *J. Am. Chem. Soc.* **1984**, *106*, 3750–3754.
(129) Chakraborty, S.; Blacque, O.; Berke, H. Ligand Assisted Carbon Dioxide Activation and Hydrogenation Using Molybdenum and Tungsten Amides. *Dalton Trans.* **2015**, *44*, 6560–6570.
(130) Zhang, Y.; Williard, P. G.; Bernskoetter, W. H. Synthesis and Characterization of Pincer-Molybdenum Precatalysts for CO_2 Hydrogenation. *Organometallics* **2016**, *35*, 860–865.
(131) Jing, Y.; Ye, Z.; Su, J.; Feng, Y.; Qu, L.-B.; Liu, Y.; Ke, Z. The Potential of d ^{6} Non-Noble Metal NHC Catalysts for Carbon Dioxide Hydrogenation: Group and Row Effects. *Catal. Sci. Technol.* **2020**, *10*, 5443–5447.
(132) Fickenscher, Z. B. G.; Lönnecke, P.; Müller, A. K.; Hollóczki, O.; Kirchner, B.; Hey-Hawkins, E. Synergistic Catalysis in Heterobimetallic Complexes for Homogeneous Carbon Dioxide Hydrogenation. *Molecules* **2023**, *28*, 2574.
(133) Singh, T.; Chakraborty, S. Molybdenum-Catalyzed Hydrogenation of Carbon Dioxide, Bicarbonate, and Inorganic Carbonates to Formates. *Dalton Trans.* **2024**, *53*, 10244–10249.
(134) Singh, T.; Gutal, A.; Regina, A.; Banerjee, A.; Paranjothy, M.; Chakraborty, S. Bench-Stable Low-Valent Chromium Catalysts for Hydrogenation of CO_2, Bicarbonate, and Inorganic Carbonates to Formate. *ACS Catal.* **2024**, 14958–14965.
(135) Wang, D.; Astruc, D. The Golden Age of Transfer Hydrogenation. *Chem. Rev.* **2015**, *115*, 6621−6686.
(136) Noyori, R.; Hashiguchi, S. *Acc. Chem. Res*. **1997**, *30*, 97−102.
(137) Brieger, G.; Nestrick, T. J. Catalytic transfer hydrogenation. *Chem. Rev*. **1974**, *74*, 567−580.
(138) Sean E. Clapham, Alen Hadzovic, Robert H. Morris, Mechanisms of the H_2-hydrogenation and transfer hydrogenation of polar bonds catalyzed by ruthenium hydride complexes, Coordination Chemistry Reviews, **2004**, *248*, 2201–2237.
(139) Crabtree, R.H. Transfer hydrogenation with glycerol as H-donor: Catalyst activation, deactivation and homogeneity. *ACS Sustain. Chem. Eng.* **2019**, *7*, 15845–15853.
(140) Ding, G.; Su, J.; Zhang, C.; Tang, K.; Yang, L.; Lin, H. Coupling Glucose Dehydrogenation with CO_2 Hydrogenation by Hydrogen Transfer in Aqueous Media at Room Temperature. *ChemSusChem* **2018,** *11*, 2029−2034.
(141) Ainembabazi, D.; Wang, K.; Finn, M.; Ridenour, J.; Voutchkova-Kostal, A. Efficient transfer hydrogenation of carbonate salts from glycerol using water-soluble iridium N-heterocyclic carbene catalysts. *Green Chem.* **2020**, *22*, 6093–6104.
(142) Cheong, Y.-J.; Sung, K.; Park, S.; Jung, J.; Jang, H.-Y. Valorization of chemical wates: Ir(biscarbene)-catalyzed transfer hydrogenation of inorganic carbonates using glycerol. *ACS Sustain. Chem. Eng*. **2020**, *8*, 6972–6978.
(143) Hietala, J.; Vuori, A.; Johnsson, P.; Pollari, I.; Reutemann, W.; Kieczka, H. Formic acid. 7th ed.; Elvers, B., Ed.; Wiley-VCH Verlag GmbH & Co: Hoboken, NJ, **2016**; Vol. A12.
(144) Grasemann, M.; Laurenczy, G. Formic acid as a hydrogen source – recent developments and future trends. *Energy Environ. Sci*. **2012**, *5*, 8171-8181.
(145) Mellmann, D.; Sponholz, P.; Junge, H.; Beller, M. Formic acid as a hydrogen storage material–development of homogeneous catalysts for selective hydrogen release. *Chem. Soc. Rev.* **2016**, *45*, 3954-3988.
(146) Sanz, S.; Benitez, M.; Peris, E. A New Approach to the Reduction of Carbon Dioxide: CO_2 Reduction to Formate by Transfer Hydrogenation in *i*PrOH. *Organometallics* **2010**, *29*, 275−277.
(147) Sanz, S.; Azua, A.; Peris, E. (η6-arene)Ru(bis-NHC)′ complexes for the reduction of CO_2 to formate with hydrogen and by transfer hydrogenation with *i*PrOH. *Dalton Trans.* **2010**, *39*, 6339−6343.
(148) Azua, A.; Sanz, S.; Peris, E. Water-Soluble IrIII N-Heterocyclic Carbene Based Catalysts for the Reduction of CO_2 to Formate by Transfer Hydrogenation and the Deuteration of Aryl Amines in Water. *Chem. - Eur. J.* **2011**, *17*, 3963−3967.
(149) Dibenedetto, A.; Stufano, P.; Nocito, F.; Aresta, M. Ru ^{II} -Mediated Hydrogen Transfer from Aqueous Glycerol to CO $_2$: From Waste to Value-Added Products. *ChemSusChem* **2011**, *4*, 1311–1315.

(150). Liu, Q.; Wu, L.; Gülak, S.; Rockstroh, N.; Jackstell, R.; Beller, M. Towards a Sustainable Synthesis of Formate Salts: Combined Catalytic Methanol Dehydrogenation and Bicarbonate Hydrogenation *Angew. Chem., Int. Ed.* **2014**, *53*, 7085−7088.
(151) Heltzel, J. M.; Finn, M.; Ainembabazi, D.; Wang, K.; Voutchkova-Kostal, A. M. Transfer hydrogenation of carbon dioxide and bicarbonate from glycerol under aqueous conditions. *Chem. Commun.* **2018**, *54*, 6184−6187.
(152) Kumar, A.; Semwal, S.; Choudhury, J. Catalytic Conversion of CO_2 to Formate with Renewable Hydrogen Donors: An Ambient-Pressure and H_2-Independent Strategy. *ACS Catal.* **2019**, *9*, 2164−2168.
(153) a) Sato, Y.; Kayaki, Y.; Ikariya, T. Transfer hydrogenation of carbon dioxide via bicarbonate promoted by bifunctional C−N chelating Cp*Ir complexes. *Chem. Commun.* **2020**, *56*, 10762−10765. b) Cheong, Y.-J.; Sung, K.; Kim, J.-A.; Kim, Y. K.; Yoon, W.; Yun, H.; Jang, H.-Y. Iridium(NHC)-Catalyzed Sustainable Transfer Hydrogenation of CO_2 and Inorganic Carbonates. *Catalysts* **2021**, *11*, 695.
(154) Kumar, A.; Bhardwaj, R.; Mandal, S. K.; Choudhury, J. Transfer Hydrogenation of CO_2 and CO_2 Derivatives Using Alcohols as Hydride Sources: Boosting an H_2 -Free Alternative Strategy. *ACS Catal.* **2022**, *12*, 8886–8903.
(155) Murray, C. J. L.; Ikuta, K. S.; Sharara, F.; Swetschinski, L.; Robles Aguilar, G.; Gray, A.; Han, C.; Bisignano, C.; Rao, P.; Wool, E.; Johnson, S. C.; Browne, A. J.; Chipeta, M. G.; Fell, F.; Hackett, S.; Haines-Woodhouse, G.; Kashef Hamadani, B. H.; Kumaran, E. A. P.; McManigal, B.; Achalapong, S.; Agarwal, R.; Akech, S.; Albertson, S.; Amuasi, J.; Andrews, J.; Aravkin, A.; Ashley, E.; Babin, F.-X.; Bailey, F.; Baker, S.; Basnyat, B.; Bekker, A.; Bender, R.; Berkley, J. A.; Bethou, A.; Bielicki, J.; Boonkasidecha, S.; Bukosia, J.; Carvalheiro, C.; Castañeda-Orjuela, C.; Chansamouth, V.; Chaurasia, S.; Chiurchiù, S.; Chowdhury, F.; Clotaire Donatien, R.; Cook, A. J.; Cooper, B.; Cressey, T. R.; Criollo-Mora, E.; Cunningham, M.; Darboe, S.; Day, N. P. J.; De Luca, M.; Dokova, K.; Dramowski, A.; Dunachie, S. J.; Duong Bich, T.; Eckmanns, T.; Eibach, D.; Emami, A.; Feasey, N.; Fisher-Pearson, N.; Forrest, K.; Garcia, C.; Garrett, D.; Gastmeier, P.; Giref, A. Z.; Greer, R. C.; Gupta, V.; Haller, S.; Haselbeck, A.; Hay, S. I.; Holm, M.; Hopkins, S.; Hsia, Y.; Iregbu, K. C.; Jacobs, J.; Jarovsky, D.; Javanmardi, F.; Jenney, A. W. J.; Khorana, M.; Khusuwan, S.; Kissoon, N.; Kobeissi, E.; Kostyanev, T.; Krapp, F.; Krumkamp, R.; Kumar, A.; Kyu, H. H.; Lim, C.; Lim, K.; Limmathurotsakul, D.; Loftus, M. J.; Lunn, M.; Ma, J.; Manoharan, A.; Marks, F.; May, J.; Mayxay, M.; Mturi, N.; Munera-Huertas, T.; Musicha, P.; Musila, L. A.; Mussi-Pinhata, M. M.; Naidu, R. N.; Nakamura, T.; Nanavati, R.; Nangia, S.; Newton, P.; Ngoun, C.; Novotney, A.; Nwakanma, D.; Obiero, C. W.; Ochoa, T. J.; Olivas-Martinez, A.; Olliaro, P.; Ooko, E.; Ortiz-Brizuela, E.; Ounchanum, P.; Pak, G. D.; Paredes, J. L.; Peleg, A. Y.; Perrone, C.; Phe, T.; Phommasone, K.; Plakkal, N.; Ponce-de-Leon, A.; Raad, M.; Ramdin, T.; Rattanavong, S.; Riddell, A.; Roberts, T.; Robotham, J. V.; Roca, A.; Rosenthal, V. D.; Rudd, K. E.; Russell, N.; Sader, H. S.; Saengchan, W.; Schnall, J.; Scott, J. A. G.; Seekaew, S.; Sharland, M.; Shivamallappa, M.; Sifuentes-Osornio, J.; Simpson, A. J.; Steenkeste, N.; Stewardson, A. J.; Stoeva, T.; Tasak, N.; Thaiprakong, A.; Thwaites, G.; Tigoi, C.; Turner, C.; Turner, P.; Van Doorn, H. R.; Velaphi, S.; Vongpradith, A.; Vongsouvath, M.; Vu, H.; Walsh, T.; Walson, J. L.; Waner, S.; Wangrangsimakul, T.; Wannapinij, P.; Wozniak, T.; Young Sharma, T. E. M. W.; Yu, K. C.; Zheng, P.; Sartorius, B.; Lopez, A. D.; Stergachis, A.; Moore, C.; Dolecek, C.; Naghavi, M. Global Burden of Bacterial Antimicrobial Resistance in 2019: A Systematic Analysis. *The Lancet* **2022**, *399*, 629–655.
(156) Butler, M. S.; Henderson, I. R.; Capon, R. J.; Blaskovich, M. A. T. Antibiotics in the Clinical Pipeline as of December 2022. *J Antibiot* **2023**, *76*, 431–473.
(157) Bhandari, V.; Suresh, A. Next-Generation Approaches Needed to Tackle Antimicrobial Resistance for the Development of Novel Therapies Against the Deadly Pathogens. *Front. Pharmacol.* **2022**, *13*, 838092.
(158) Dasari, S.; Bernard Tchounwou, P. Cisplatin in Cancer Therapy: Molecular Mechanisms of Action. *European Journal of Pharmacology* **2014**, *740*, 364–378.
(159) Dubar, F.; Khalife, J.; Brocard, J.; Dive, D.; Biot, C. Ferroquine, an Ingenious Antimalarial Drug –Thoughts on the Mechanism of Action. *Molecules* **2008**, *13*, 2900–2907.

(160) Reedijk, J. *Reference Module in Chemistry, Molecular Sciences and Chemical Engineering*; Elsevier, 2013.
(161) Li, Z.; Yan, H.; Chang, G.; Hong, M.; Dou, J.; Niu, M. Cu(II), Ni(II) Complexes Derived from Chiral Schiff-Base Ligands: Synthesis, Characterization, Cytotoxicity, Protein and DNA–Binding Properties. *Journal of Photochemistry and Photobiology B: Biology* **2016**, *163*, 403–412.
(162) Dhara, K.; Roy, P.; Ratha, J.; Manassero, M.; Banerjee, P. Synthesis, Crystal Structure, Magnetic Property and DNA Cleavage Activity of a New Terephthalate-Bridged Tetranuclear Copper(II) Complex. *Polyhedron* **2007**, *26*, 4509–4517.
(163) Alreja, P.; Kaur, N. Probing Anion and Cation with Novel Salicylidene Schiff Base Receptor Appended with 1, 10-Phenanthroline: Mimicking INHIBIT Molecular Logic Gate. *Inorganica Chimica Acta* **2018**, *480*, 127–131.
(164) Yufanyi, D. M.; Abbo, H. S.; Titinchi, S. J. J.; Neville, T. Platinum(II) and Ruthenium(II) Complexes in Medicine: Antimycobacterial and Anti-HIV Activities. *Coordination Chemistry Reviews* **2020**, *414*, 213285.
(165) Smitten, K. L.; Fairbanks, S. D.; Robertson, C. C.; Bernardino De La Serna, J.; Foster, S. J.; Thomas, J. A. Ruthenium Based Antimicrobial Theranostics – Using Nanoscopy to Identify Therapeutic Targets and Resistance Mechanisms in *Staphylococcus Aureus*. *Chem. Sci.* **2020**, *11*, 70–79.
(166) Li, F.; Harry, E. J.; Bottomley, A. L.; Edstein, M. D.; Birrell, G. W.; Woodward, C. E.; Keene, F. R.; Collins, J. G. Dinuclear Ruthenium(II) Antimicrobial Agents That Selectively Target Polysomes in Vivo. *Chem. Sci.* **2014**, *5*, 685–693.
(167) Li, F.; Feterl, M.; Mulyana, Y.; Warner, J. M.; Collins, J. G.; Keene, F. R. In Vitro Susceptibility and Cellular Uptake for a New Class of Antimicrobial Agents: Dinuclear Ruthenium(II) Complexes. *Journal of Antimicrobial Chemotherapy* **2012**, *67*, 2686–2695.
(168) Frei, A.; Amado, M.; Cooper, M. A.; Blaskovich, M. A. T. Light-Activated Rhenium Complexes with Dual Mode of Action against Bacteria. *Chemistry A European J* **2020**, *26* (13), 2852–2858.
(169) Sovari, S. N.; Radakovic, N.; Roch, P.; Crochet, A.; Pavic, A.; Zobi, F. Combatting AMR: A Molecular Approach to the Discovery of Potent and Non-Toxic Rhenium Complexes Active against C. Albicans-MRSA Co-Infection. *European Journal of Medicinal Chemistry* **2021**, *226*, 113858.
(170) Betts, J.; Nagel, C.; Schatzschneider, U.; Poole, R.; La Ragione, R. M. Antimicrobial Activity of Carbon Monoxide-Releasing Molecule [Mn(CO)3(Tpa-κ3N)]Br versus Multidrug-Resistant Isolates of Avian Pathogenic Escherichia Coli and Its Synergy with Colistin. *PLoS ONE* **2017**, *12*, e0186359.
(171) Rana, N.; Jesse, H. E.; Tinajero-Trejo, M.; Butler, J. A.; Tarlit, J. D.; Von Und Zur Muhlen, M. L.; Nagel, C.; Schatzschneider, U.; Poole, R. K. A Manganese Photosensitive Tricarbonyl Molecule [Mn(CO)3(Tpa-K3 N)]Br Enhances Antibiotic Efficacy in a Multi-Drug-Resistant Escherichia Coli. *Microbiology* **2017**, *163*, 1477–1489.
(172) Nair, M. S.; Arish, D.; Joseyphus, R. S. Synthesis, Characterization, Antifungal, Antibacterial and DNA Cleavage Studies of Some Heterocyclic Schiff Base Metal Complexes. *Journal of Saudi Chemical Society* **2012**, *16*, 83–88.
(173) Shaker, A. M.; Nassr, L. A.-M. E.; Adam, M. S. S.; Mohamed, I. M. A. Kinetics of Acid Hydrolysis and Reactivity of Some Antibacterial Hydrophilic Iron(II) Imino-Complexes. *Russ. J. Phys. Chem.* **2015**, *89*, 759–765.
(174) Abu-Dief, A. M.; Mohamed, I. M. A. A Review on Versatile Applications of Transition Metal Complexes Incorporating Schiff Bases. *Beni-Suef University Journal of Basic and Applied Sciences* **2015**, *4*, 119–133.
(175) Mohamed, G. G.; Omar, M. M.; Hindy, A. M. M. Synthesis, Characterization and Biological Activity of Some Transition Metals with Schiff Base Derived from 2-Thiophene Carboxaldehyde and Aminobenzoic Acid. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* **2005**, *62*, 1140–1150.

(176) Kaya, M.; Yenikaya, C.; Colak, A. T.; Colak, F. Synthesis, Spectral, Thermal and Biological Studies of Co(III) and Binuclear Ni(II) Complexes with a Novel Amine-Imine-Oxime Ligand. *Russ J Gen Chem* **2008**, *78*, 1808–1815.
(177) *The Handbook of Homogeneous Hydrogenation*, 1st ed.; De Vries, J. G., Elsevier, C. J., Eds.; Wiley, 2006.
(178) Shvo, Youval.; Czarkie, Dorotha.; Rahamim, Yocheved.; Chodosh, D. F. A New Group of Ruthenium Complexes: Structure and Catalysis. *J. Am. Chem. Soc.* **1986**, *108*, 7400–7402.
(179) Casey, C. P.; Guan, H. An Efficient and Chemoselective Iron Catalyst for the Hydrogenation of Ketones. *J. Am. Chem. Soc.* **2007**, *129*, 5816–5817.
(180) Milstein, D. Discovery of Environmentally Benign Catalytic Reactions of Alcohols Catalyzed by Pyridine-Based Pincer Ru Complexes, Based on Metal–Ligand Cooperation. *Top Catal* **2010**, *53*, 915–923.
(181) Werkmeister, S.; Junge, K.; Beller, M. Catalytic Hydrogenation of Carboxylic Acid Esters, Amides, and Nitriles with Homogeneous Catalysts. *Org. Process Res. Dev.* **2014**, *18*, 289–302.
(182) Holzwarth, M. S.; Plietker, B. Biorelevant Metals in Sustainable Metal Catalysis-A Survey. *ChemCatChem* **2013**, *5*, 1650–1679.
(183) Bullock, R. M. Catalytic Ionic Hydrogenations. *Chemistry A European J* **2004**, *10*, 2366–2374.
(184) Schrock, R. R.; Hoveyda, A. H. Molybdenum and Tungsten Imido Alkylidene Complexes as Efficient Olefin-Metathesis Catalysts. *Angew Chem Int Ed* **2003**, *42*, 4592–4633.
(185) Schrock, R. R. Recent Advances in High Oxidation State Mo and W Imido Alkylidene Chemistry. *Chem. Rev.* **2009**, *109*, 3211–3226.
(186) Hoveyda, A. H.; Zhugralin, A. R. The Remarkable Metal-Catalysed Olefin Metathesis Reaction. *Nature* **2007**, *450*, 243–251.
(187) Tooley, P. A.; Ovalles, Cesar.; Kao, S. C.; Darensbourg, D. J.; Darensbourg, M. Y. Anionic Group 6 Hydrides and Carboxylates as Homogeneous Catalysts for Reduction of Aldehydes and Ketones. *J. Am. Chem. Soc.* **1986**, *108*, 5465–5470.
(188) Bullock, R. M.; Voges, M. H. Homogeneous Catalysis with Inexpensive Metals: Ionic Hydrogenation of Ketones with Molybdenum and Tungsten Catalysts. *J. Am. Chem. Soc.* **2000**, *122*, 12594–12595.
(189) Kimmich, B. F. M.; Fagan, P. J.; Hauptman, E.; Bullock, R. M. Solvent-Free Ketone Hydrogenations Catalyzed by Molybdenum complexes *Chem. Commun.* **2004**, No. 8, 1014.
(190) Baricelli, P. J.; Melean, L. G.; Ricardes, S.; Guanipa, V.; Rodriguez, M.; Romero, C.; Pardey, A. J.; Moya, S.; Rosales, M. Mo(CO)3(NCMe)(PPh3)2: Synthesis, X-Ray Structure and Evaluation of Its Catalytic Activity for the Homogeneous Hydrogenation of Olefins and Their Mixtures. *Journal of Organometallic Chemistry* **2009**, *694*, 3381–3385.
(191) Zhu, G.; Pang, K.; Parkin, G. New Modes for Coordination of Aromatic Heterocyclic Nitrogen Compounds to Molybdenum: Catalytic Hydrogenation of Quinoline, Isoquinoline, and Quinoxaline by $Mo(PMe_3)_4H_4$. *J. Am. Chem. Soc.* **2008**, *130*, 1564–1565.
(192) Chakraborty, S.; Blacque, O.; Fox, T.; Berke, H. Highly Active, Low-Valence Molybdenum- and Tungsten-Amide Catalysts for Bifunctional Imine-Hydrogenation Reactions. *Chemistry An Asian Journal* **2014**, *9*, 328–337.
(193) Leischner, T.; Spannenberg, A.; Junge, K.; Beller, M. Molecular Defined Molybdenum–Pincer Complexes and Their Application in Catalytic Hydrogenations. *Organometallics* **2018**, *37*, 4402–4408.
(194) Joannou, M. V.; Bezdek, M. J.; Chirik, P. J. Pyridine(Diimine) Molybdenum-Catalyzed Hydrogenation of Arenes and Hindered Olefins: Insights into Precatalyst Activation and Deactivation Pathways. *ACS Catal.* **2018**, *8*, 5276–5285.
(195) Both, N. F.; Spannenberg, A.; Junge, K.; Beller, M. Low-Valent Molybdenum PNP Pincer Complexes as Catalysts for the Semihydrogenation of Alkynes. *Organometallics* **2022**, *41*, 1797–1805.
(196) Chakraborty, S.; Blacque, O.; Fox, T.; Berke, H. Trisphosphine-Chelate-Substituted Molybdenum and Tungsten Nitrosyl Hydrides as Highly Active Catalysts for Olefin Hydrogenations. *Chemistry A European J* **2014**, *20*, 12641–12654.

(197) Chakraborty, S.; Berke, H. Homogeneous Hydrogenation of Nitriles Catalyzed by Molybdenum and Tungsten Amides. *ACS Catal.* **2014**, *4*, 2191–2194.
(198) Leischner, T.; Spannenberg, A.; Junge, K.; Beller, M. Synthesis of Molybdenum Pincer Complexes and Their Application in the Catalytic Hydrogenation of Nitriles. *ChemCatChem* **2020**, *12*, 4543–4549.
(199) Leischner, T.; Artús Suarez, L.; Spannenberg, A.; Junge, K.; Nova, A.; Beller, M. Highly Selective Hydrogenation of Amides Catalysed by a Molybdenum Pincer Complex: Scope and Mechanism. *Chem. Sci.* **2019**, *10*, 10566–10576.
(200) Viereck, P.; Hierlmeier, G.; Tosatti, P.; Pabst, T. P.; Puentener, K.; Chirik, P. J. Molybdenum-Catalyzed Asymmetric Hydrogenation of Fused Arenes and Heteroarenes. *J. Am. Chem. Soc.* **2022**, *144*, 11203–11214.
(201) Hierlmeier, G.; Tosatti, P.; Puentener, K.; Chirik, P. J. Identification of Cyclohexadienyl Hydrides as Intermediates in Molybdenum-Catalyzed Arene Hydrogenation. *Angew Chem Int Ed* **2023**, *62*, e202216026.
(202) Singh, T.; Jalwal, S.; Chakraborty, S. Homogeneous First-row Transition-metal-catalyzed Carbon Dioxide Hydrogenation to Formic Acid/Formate, and Methanol. *Asian J Org Chem* **2022**, *11*, e202200330.
(203) Both, N. F.; Thaens, J.; Spannenberg, A.; Jiao, H.; Junge, K.; Beller, M. Hydrogenation of Esters Catalyzed by Bis(*N* -Heterocyclic Carbene) Molybdenum Complexes. *ACS Catal.* **2024**, 4082–4092.
(204) Wang, W.-H.; Himeda, Y.; Muckerman, J. T.; Manbeck, G. F.; Fujita, E. CO_2 Hydrogenation to Formate and Methanol as an Alternative to Photo- and Electrochemical CO_2 Reduction. *Chem. Rev.* **2015**, *115*, 12936–12973.
(205) Tanaka, R.; Yamashita, M.; Nozaki, K. Catalytic Hydrogenation of Carbon Dioxide Using Ir(III)−Pincer Complexes. *J. Am. Chem. Soc.* **2009**, *131*, 14168–14169.
(206) Birkholz (Née Gensow), M.-N.; Freixa, Z.; Van Leeuwen, P. W. N. M. Bite Angle Effects of Diphosphines in C–C and C–X Bond Forming Cross Coupling Reactions. *Chem. Soc. Rev.* **2009**, *38*, 1099.
(207) Mansell, S. M. Catalytic Applications of Small Bite-Angle Diphosphorus Ligands with Single-Atom Linkers. *Dalton Trans.* **2017**, *46*, 15157–15174.
(208) Dierkes, P.; Van Leeuwen, P. W. N. M. The Bite Angle Makes the Difference: A Practical Ligand Parameter for Diphosphine Ligands. *J. Chem. Soc., Dalton Trans.* **1999**, No. 10, 1519–1530.
(209) Becica, J.; Glaze, O. D.; Wozniak, D. I.; Dobereiner, G. E. Selective Isomerization of Terminal Alkenes to (*Z*)-2-Alkenes Catalyzed by an Air-Stable Molybdenum(0) Complex. *Organometallics* **2018**, *37*, 482–490.
(210) Berstler, J.; Lopez, A.; Ménard, D.; Dougherty, W. G.; Kassel, W. S.; Hansen, A.; Daryaei, A.; Ashitey, P.; Shaw, M. J.; Fey, N.; Nataro, C. Synthesis and Spectroelectrochemistry of Transition Metal Carbonyls with 1,1′-Bis(Phosphino)Metallocene Ligands. *Journal of Organometallic Chemistry* **2012**, *712*, 37–45.
(211) Birdwhistell, K. R.; Schulz, B. E.; Dizon, P. M. Rapid Synthesis of Group VI Carbonyl Complexes by Coupling Borohydride Catalysis and Microwave Heating. *Inorganic Chemistry Communications* **2012**, *26*, 69–71.
(212) Boddien, A.; Gärtner, F.; Federsel, C.; Sponholz, P.; Mellmann, D.; Jackstell, R.; Junge, H.; Beller, M. CO_2 -"Neutral" Hydrogen Storage Based on Bicarbonates and Formates. *Angew Chem Int Ed* **2011**, *50*, 6411–6414.
(213) Wei, D.; Shi, X.; Sponholz, P.; Junge, H.; Beller, M. Manganese Promoted (Bi)Carbonate Hydrogenation and Formate Dehydrogenation: Toward a Circular Carbon and Hydrogen Economy. *ACS Cent. Sci.* **2022**, *8*, 1457–1463.
(214) Sinha, A.; Ghatak, T.; Bera, J. K. Hydroxycarbonyl Complexes as Key Intermediates in the Base-Assisted Reduction of Ruthenium Carbonyls. *Dalton Trans.* **2010**, *39* , 11301.
(215) Bowman, K.; Deeming, A. J.; Proud, G. P. Acidic and Basic Properties of the Hydroxycarbonyl Complex [IrCl2(CO2H)(CO)(PMe2Ph)2]. *J. Chem. Soc., Dalton Trans.* **1985**, No. 4, 857.

(216) Halpern, J. Oxidation of Organometallic Compounds. *Angew. Chem. Int. Ed. Engl.* **1985**, *24*, 274–282.
(217) Li, W.; Huang, M.; Liu, J.; Huang, Y.-L.; Lan, X.-B.; Ye, Z.; Zhao, C.; Liu, Y.; Ke, Z. Enhanced Hydride Donation Achieved Molybdenum Catalyzed Direct *N* -Alkylation of Anilines or Nitroarenes with Alcohols: From Computational Design to Experiment. *ACS Catal.* **2021**, *11*, 10377–10382.
(218) Liu, J.; Li, W.; Li, Y.; Liu, Y.; Ke, Z. Selective C-alkylation Between Alcohols Catalyzed by N-Heterocyclic Carbene Molybdenum. *Chemistry An Asian Journal* **2021**, *16*, 3124–3128.
(219) Klankermayer, J.; Wesselbaum, S.; Beydoun, K.; Leitner, W. Selective Catalytic Synthesis Using the Combination of Carbon Dioxide and Hydrogen: Catalytic Chess at the Interface of Energy and Chemistry. *Angew. Chem. Int. Ed.* **2016**, *55*, 7296-7343.
(220) Moret, S.; Dyson, P. J.; Laurenczy, G. Direct synthesis of formic acid from carbon dioxide by hydrogenation in acidic media. *Nat Commun.* **2014**, *5*, 4017.
(221) Huff, C.; Sanford, M. Catalytic CO_2 Hydrogenation to Formate by a Ruthenium Pincer Complex. *ACS Catal.* **2013**, *3*, 2412–2416.
(222) Kallmeier, F.; Fertig, R.; Irrgang, T.; Kempe, R. Chromium-Catalyzed Alkylation of Amines by Alcohols. *Angew. Chem. Int. Ed.* **2020**, *59*, 11789-11793.
(223) Miao, Y.; Samuelsen, S. V.; Madsen, R. Vanadium- and Chromium-CatalyzedDehydrogenative Synthesis of Imines from Alcohols and Amines. *Organometallics* **2021**, *40*, 1328-1335.
(224) Narjinari, H.; Tanwar, N.; Kathuria, L.; Jasra, R. V.; Kumar, A. Guerbet-type β-alkylation of secondary alcohols catalyzed by chromium chloride and its corresponding NNN pincer complex. *Catal. Sci. Technol.* **2022**, *12*, 4753-4762.
(225) Su, P.; Chen, Z.; Ni, J.; Yang, Z.; Li, Y.; Ke, Z. Surmounting Alkoxide Trap Strategy: *N* -Heterocyclic Carbene Chromium(0)-Catalyzed *C* -Alkylation between Alcohols. *ACS Catal.* **2023**, *13*, 12481–12493.
(226) Singh, T.; Atreya, V.; Jalwal, S.; Anand, A.; Chakraborty, S. Advances in Group VI Metal-Catalyzed Homogeneous Hydrogenation and Dehydrogenation Reactions. *Chem. Asian J.* **2023**, *18*, e202300758.
(227) Frankel, E. N.; Selke, E.; Glass, C. A. Homogeneous 1,4-addition of hydrogen catalyzed by tricarbonyl(arene)chromium complexes. *J. Am. Chem. Soc.* **1968**, *90*, 2446-2448.
(228) Tooley, P. A.; Ovalles, C.; Kao, S. C.; Darensbourg, D. J.; Darensbourg, M. Y. Anionic group 6 hydrides and carboxylates as homogeneous catalysts for reduction of aldehydes and ketones. *J. Am. Chem. Soc.* **1986**, *108*, 5465-5470.
(229) Vielhaber, T.; Faust, K.; Topf, C. Group 6 Metal Carbonyl Complexes Supported by a Bidentate PN Ligand: Syntheses, Characterization, and Catalytic Hydrogenation Activity. *Organometallics* **2020**, *39*, 4535-4543.
(230) Han, B.; Ma, P.; Cong, X.; Chen, H.; Zeng, X. Chromium- and Cobalt-Catalyzed, Regiocontrolled Hydrogenation of Polycyclic Aromatic Hydrocarbons: A Combined Experimental and Theoretical Study. *J.*
Am. Chem. Soc. **2019**, *141*, 9018-9026.
(231) Gregori, B. J.; Schmotz, M.-O. W. S.; Jacobi von Wangelin, A. Stereoselective Semi-Hydrogenations of Alkynes by First-Row (3d) Transition Metal Catalysts. *ChemCatChem* **2022**, *14*, e202200886.
(232) Ling, L.; Hu, C.; Long, L.; Zhang, X.; Zhao, L.; Liu, L. L.; Chen, H.; Luo, M.; Zeng, X. Chromium-catalyzedstereodivergent E- and Z-selective alkyne hydrogenation controlled by cyclic (alkyl)(amino)carbene ligands. *Nat Commun* **2023**, *14*, 990.
(233) Birchall, N.; Hennhöfer, F.; Nieger, M.; Gudat, D. Chromium Complexes with Benzanellated N-Heterocyclic Phosphenium Ligands–Synthesis, Reactivity and Application in Catalytic CO_2 Reduction. *Chemistry A European J* **2024**, *30*, e202401714.
(234) (a) Carvajal, M. À.; Kozuch, S.; Shaik, S. Factors Controlling the Selective Hydroformylation of Internal Alkenes to Linear Aldehydes. 1. The Isomerization Step. *Organometallics* **2009**, *28*, 3656-3665.

(235) Freixa, Z.; Van Leeuwen, P. W. N. M. Bite Angle Effects in Diphosphine Metal Catalysts: Steric or Electronic? *Dalton Trans* **2003**, *10*, 1890–1901.
(236) Ozer, Z.; Ozkar, S. ^{13}C and ^{31}P NMR Study of Tetracarbonylbis (Diphenylphosphino) Alkanemetal(0) Complexes of The Group 6 Elements. *Turk. J. Chem*. **1999**, *23*, 9– 14.
(237) Ohs, A. C.; Rheingold, A. L.; Shaw, M. J.; Nataro, C. Electrochemistry of Group VI Metal Carbonyl Compounds Containing 1,1'-Bis(Diphenylphosphino)Ferrocene. *Organometallics* **2004**, *23*, 4655–4660.
(238) Kim, Y.; Ryu, S.; Cho, W.; Kim, M.; Park, M. H.; Kim, Y. Halide-Free and Bifunctional One-Component Catalysts for the Coupling of Carbon Dioxide and Epoxides. *Inorg. Chem*. **2019**, *58*, 5922– 5931.
(239) An, B.; Zeng, L.; Jia, M.; Li, Z.; Lin, Z.; Song, Y.; Zhou, Y.; Cheng, J.; Wang, C.; Lin, W. Molecular Iridium Complexes in Metal–Organic Frameworks Catalyze CO_2 Hydrogenation via Concerted Proton and Hydride Transfer. *J. Am. Chem. Soc.* **2017**, *139*, 17747–17750.
(240) Xu, X.; Truhlar, D. G. Performance of Effective Core Potentials for Density Functional Calculations on 3d Transition Metals. *J. Chem. Theory Comput.* **2012**, *8* , 80–90.
(241) Neese, F. Software Update: The ORCA Program System—Version 5.0. *WIREs Comput Mol Sci* **2022**, *12*.
(241) Takano, Y.; Houk, K. N. Benchmarking the Conductor-like Polarizable Continuum Model (CPCM) for Aqueous Solvation Free Energies of Neutral and Ionic Organic Molecules. *J. Chem. Theory Comput.* **2005**, *1*, 70–77.
(242) Piccirilli, L.; Lobo Justo Pinheiro, D.; Nielsen, M. Recent Progress with Pincer Transition Metal Catalysts for Sustainability. *Catalysts* **2020**, *10*, 773.
(243) Frankel, E. Mechanism of Hydrogen Transfer Reactions in 1,4-Cyclohexadiene and 1,4-Hexadiene Catalyzed by Tricarbonyl Chromium Complexes. *Journal of Catalysis* **1972**, *24* , 358–360.
(244) Peris, E.; Crabtree, R. H. Key Factors in Pincer Ligand Design. *Chem. Soc. Rev.* **2018**, *47*, 1959–1968.
(245) Grützmacher, H. Cooperating Ligands in Catalysis. *Angew Chem Int Ed* **2008**, *47*, 1814–1818.
(246) Khusnutdinova, J. R.; Milstein, D. Metal-Ligand Cooperation. *Angew. Chem. Int. Ed.* **2015**, *54*, 12236–12273.
(247) Stevens, M. A.; Colebatch, A. L. Cooperative Approaches in Catalytic Hydrogenation and Dehydrogenation. *Chem. Soc. Rev.* **2022**, *51*, 1881–1898.
(248) Gunanathan, C.; Milstein, D. Metal–Ligand Cooperation by Aromatization–Dearomatization: A New Paradigm in Bond Activation and "Green" Catalysis. *Acc. Chem. Res.* **2011**, *44*, 588–602.
(249) Noyori, R.; Ohkuma, T. Asymmetric Catalysis by Architectural and Functional Molecular Engineering: Practical Chemo- and Stereoselective Hydrogenation of Ketones. *Angew. Chem. Int. Ed.* **2001**, *40*, 40–73.
(250) Muñiz, K. Bifunctional Metal–Ligand Catalysis: Hydrogenations and New Reactions within the Metal–(Di)Amine Scaffold. *Angew Chem Int Ed* **2005**, *44*, 6622–6627.
(251) Noyori, R.; Yamakawa, M.; Hashiguchi, S. Metal−Ligand Bifunctional Catalysis: A Nonclassical Mechanism for Asymmetric Hydrogen Transfer between Alcohols and Carbonyl Compounds. *J. Org. Chem.* **2001**, *66*, 7931–7944.
(252) Zell, T.; Milstein, D. Hydrogenation and Dehydrogenation Iron Pincer Catalysts Capable of Metal–Ligand Cooperation by Aromatization/Dearomatization. *Acc. Chem. Res.* **2015**, *48*, 1979–1994.
(253) *Modern Reduction Methods*, 1st ed.; Andersson, P. G., Munslow, I. J., Eds.; Wiley, 2008.
(254) Das, K.; Waiba, S.; Jana, A.; Maji, B. Manganese-Catalyzed Hydrogenation, Dehydrogenation, and Hydroelementation Reactions. *Chem. Soc. Rev.* **2022**, *51*, 4386–4464.
(255) Dayan, A. D.; Paine, A. J. Mechanisms of Chromium Toxicity, Carcinogenicity and Allergenicity: Review of the Literature from 1985 to 2000. *Hum Exp Toxicol* **2001**, *20*, 439–451.

(256) Bowden, K.; Heilbron, I.; Jones, E. R. H.; Sargent, K. H. 313. Researches on Acetylenic Compounds. Part XII. The Preparation of Conjugated Diacetylenic Glycols by the Oxidative Coupling of Various Types of Ethynylcarbinols. *J. Chem. Soc.* **1947**, 1579.
(257) Fürstner, A. Carbon−Carbon Bond Formations Involving Organochromium(III) Reagents. *Chem. Rev.* **1999**, *99*, 991–1046.
(258) Agapie, T. Selective Ethylene Oligomerization: Recent Advances in Chromium Catalysis and Mechanistic Investigations. *Coordination Chemistry Reviews* **2011**, *255*, 861–880.
(259) Li, J.; Knochel, P. Chromium-Catalyzed Cross-Couplings and Related Reactions. *Synthesis* **2019**, *51*, 2100–2106.
(260) Li, H.; Zhao, J.; Luo, L.; Du, J.; Zeng, J. Symmetry-Breaking Sites for Activating Linear Carbon Dioxide Molecules. *Acc. Chem. Res.* **2021**, *54*, 1454–1464.
(261) O'Reilly, M. E.; Veige, A. S. Trianionic Pincer and Pincer-Type Metal Complexes and Catalysts. *Chem. Soc. Rev.* **2014**, *43*, 6325–6369.
(262) Cais, M.; Frankel, E. N.; Rejoan, A. Organometallic Studies, XXIV. Selective Hydrogenation of Conjugated Olefins Catalyzed by Arene Chromium Tricarbonyl Complexes. *Tetrahedron Letters* **1968**, *9*, 1919–1923.
(263) Awl, R. A.; Frankel, E. N.; Friedrich, J. P.; Pryde, E. H. Cis-bond-producing Hydrogenation of Polyunsaturates Catalyzed by Polymer-complexed $Cr(CO)_3$ Catalysts. *J Americ Oil Chem Soc* **1978**, *55*, 577–582.
(264) Schroeder, M. A.; Wrighton, M. S. Tris(Acetonitrile)Tricarbonylchromium(0) Catalyzed 1,4-Addition of Hydrogen to 1,3-Dienes. *Journal of Organometallic Chemistry* **1974**, *74*, C29–C32.
(265) Kramarz, W.; Kurek, S. S. A Chromium Catalyst Derived from Triallylchromium Active for Alkene Hydrogenation. *Journal of Molecular Catalysis* **1985**, *33*, 305–310.
(266) Fuchikami, T.; Ubukata, Y.; Tanaka, Y. New Reagents. V. Reducing Reagents. Catalysts for Hydrogenation and Hydrosilylation: Group 6 Anionic .MU.-Hydride Complexes(M2H(CO)10)-. *J. Syn. Org. Chem., Jpn.* **1990**, *48*, 1022–1023.
(267) Pal□gyi, J.; Nagy-Magos, Z.; Mark□, L. Hydrogenation of Schiff Bases with Group 6 Metal Carbonyls and Sodium Methoxide as Catalyst Precursors. *Transition Met Chem* **1985**, *10*, 336–338.
(268) Timelthaler, D.; Topf, C. Chromium-Catalyzed Transfer Hydrogenation of Aromatic Aldehydes Facilitated by a Simple Metal Carbonyl Complex. *Journal of Catalysis* **2022**, *413*, 478–486.
(269) McGuinness, D. S.; Brown, D. B.; Tooze, R. P.; Hess, F. M.; Dixon, J. T.; Slawin, A. M. Z. Ethylene Trimerization with Cr−PNP and Cr−SNS Complexes: Effect of Ligand Structure, Metal Oxidation State, and Role of Activator on Catalysis. *Organometallics* **2006**, *25*, 3605–3610.
(270) Ricci, G.; Boglia, A.; Motta, T. Synthesis of New Cr(II) Complexes with Bidentate Phosphine Ligands and Their Behavior in the Polymerization of Butadiene. *Journal of Molecular Catalysis A: Chemical* **2007**, *267*, 102–107.
(271) Ellermann, J.; Moll, M.; Will, N. Chemie polyfunktioneller moleküle CV. Chrom-, molybdän- und wolframtricarbonyl-komplexe des bis(2-diphenylphosphinoethyl)amins. *Journal of Organometallic Chemistry* **1989**, *378*, 73–79.
(272) McGuinness, D. S.; Wasserscheid, P.; Morgan, D. H.; Dixon, J. T. Ethylene Trimerization with Mixed-Donor Ligand (N,P,S) Chromium Complexes: Effect of Ligand Structure on Activity and Selectivity. *Organometallics* **2005**, *24*, 552–556. (273) Sanz-Perez, E. S.; Murdock, C. R.; Didas, S. A.; Jones, C. W. *Chem. Rev*. **2016**, *116*, 11840−11876.
(274) Chang, A. C. C.; Chang, H.-F.; Lin, F.-J.; Lin, K.-H.; Chen, C.-H. Biomass Gasification for Hydrogen Production. Int. *J. Hydrogen Energy* **2011**, 36, 14252−14260.
(275) Cortright, R. D.; Davda, R. R.; Dumesic, J. A. Hydrogen from Catalytic Reforming of Biomass-Derived Hydrocarbons in Liquid Water. *Nature* **2002,** *418*, 964−967.
(276) Trincado, M.; Banerjee, D.; Grutzmacher, H. Molecular Catalysts for Hydrogen Production from Alcohols. *Energy Environ. Sci*. **2014**, *7*, 2464−2503.
(277) Zhang, Y. Carbon dioxide utilization: A carbon-neutral energy cycle. *Nat. Rev. Chem.* **2017**, *1*, 0057.

(278) Hull, J. F.; Himeda, Y.; Wang, W. H.; Hashiguchi, B.; Periana, R.; Szalda, D. J.; Muckerman, J. T.; Fujita, E. Reversible Hydrogen Storage using CO_2 and a Proton-Switchable Iridium Catalyst in Aqueous Media under Mild Temperatures and Pressures. *Nat. Chem.* **2012**, *4*, 383−388.
(279) Kanega, R.; Onishi, N.; Szalda, D. J.; Ertem, M. Z.; Muckerman, J. T.; Fujita, E.; Himeda, Y. CO2 Hydrogenation Catalysts with Deprotonated Picolinamide Ligands. *ACS Catal.* **2017**,*7*, 6426−6429.
(280) Wang, L.; Onishi, N.; Murata, K.; Hirose, T.; Muckerman, J. T.; Fujita, E.; Himeda, Y. Efficient Hydrogen Storage and Production Using a Catalyst with an Imidazoline-Based, Proton-Responsive Ligand. *ChemSusChem* **2017**, *10*, 1071−1075.
(281) Maenaka, Y.; Suenobu, T.; Fukuzumi, S. Catalytic Interconversion between Hydrogen and Formic Acid at Ambient Temperature and Pressure. *Energy Environ. Sci.* **2012,** *5*, 7360−7367.
(282) Brunet, J.-J.; Chauvin, R.; Leglaye, P. Catalytic Transfer Hydrogenation of Ketones with $KHCr(CO)_5/HCO_2H/Et_3N$ Systems. *Eur. J. Inorg. Chem.* **1999**, *1999*, 713–716.
(283) Liu, X.; Werner, T. Indirect Reduction of CO_2 and Recycling of Polymers by Manganese-Catalyzed Transfer Hydrogenation of Amides, Carbamates, Urea Derivatives, and Polyurethanes. *Chem. Sci.* **2021**, *12*, 10590–1059.
(284) Zhang, S.; Bullock, R. M. Molybdenum Hydride and Dihydride Complexes Bearing Diphosphine Ligands with a Pendant Amine: Formation of Complexes with Bound Amines. *Inorg. Chem.* **2015**, *54*, 6397–6409.
(285) Brereton, K. R.; Smith, N. E.; Hazari, N.; Miller, A. J. M. Thermodynamic and Kinetic Hydricity of Transition Metal Hydrides. *Chem. Soc. Rev.* **2020**, *49*, 7929–7948.
(286) Endale, H.; Mathewos, M.; Abdeta, D. Potential Causes of Spread of Antimicrobial Resistance and Preventive Measures in One Health Perspective-A Review. *IDR* **2023**, *Volume 16*, 7515–7545.
(287) Bharadwaj, A.; Rastogi, A.; Pandey, S.; Gupta, S.; Sohal, J. S. Multidrug-Resistant Bacteria: Their Mechanism of Action and Prophylaxis. *BioMed Research International* **2022**, *2022*, 1–17.
(288) Ikuta, K. S.; Swetschinski, L. R.; Robles Aguilar, G.; Sharara, F.; Mestrovic, T.; Gray, A. P.; Davis Weaver, N.; Wool, E. E.; Han, C.; Gershberg Hayoon, A.; Aali, A.; Abate, S. M.; Abbasi-Kangevari, M.; Abbasi-Kangevari, Z.; Abd-Elsalam, S.; Abebe, G.; Abedi, A.; Abhari, A. P.; Abidi, H.; Aboagye, R. G.; Absalan, A.; Abubaker Ali, H.; Acuna, J. M.; Adane, T. D.; Addo, I. Y.; Adegboye, O. A.; Adnan, M.; Adnani, Q. E. S.; Afzal, M. S.; Afzal, S.; Aghdam, Z. B.; Ahinkorah, B. O.; Ahmad, A.; Ahmad, A. R.; Ahmad, R.; Ahmad, S.; Ahmad, S.; Ahmadi, S.; Ahmed, A.; Ahmed, H.; Ahmed, J. Q.; Ahmed Rashid, T.; Ajami, M.; Aji, B.; Akbarzadeh-Khiavi, M.; Akunna, C. J.; Al Hamad, H.; Alahdab, F.; Al-Aly, Z.; Aldeyab, M. A.; Aleman, A. V.; Alhalaiqa, F. A. N.; Alhassan, R. K.; Ali, B. A.; Ali, L.; Ali, S. S.; Alimohamadi, Y.; Alipour, V.; Alizadeh, A.; Aljunid, S. M.; Allel, K.; Almustanyir, S.; Ameyaw, E. K.; Amit, A. M. L.; Anandavelane, N.; Ancuceanu, R.; Andrei, C. L.; Andrei, T.; Anggraini, D.; Ansar, A.; Anyasodor, A. E.; Arabloo, J.; Aravkin, A. Y.; Areda, D.; Aripov, T.; Artamonov, A. A.; Arulappan, J.; Aruleba, R. T.; Asaduzzaman, M.; Ashraf, T.; Athari, S. S.; Atlaw, D.; Attia, S.; Ausloos, M.; Awoke, T.; Ayala Quintanilla, B. P.; Ayana, T. M.; Azadnajafabad, S.; Azari Jafari, A.; B, D. B.; Badar, M.; Badiye, A. D.; Baghcheghi, N.; Bagherieh, S.; Baig, A. A.; Banerjee, I.; Barac, A.; Bardhan, M.; Barone-Adesi, F.; Barqawi, H. J.; Barrow, A.; Baskaran, P.; Basu, S.; Batiha, A.-M. M.; Bedi, N.; Belete, M. A.; Belgaumi, U. I.; Bender, R. G.; Bhandari, B.; Bhandari, D.; Bhardwaj, P.; Bhaskar, S.; Bhattacharyya, K.; Bhattarai, S.; Bitaraf, S.; Buonsenso, D.; Butt, Z. A.; Caetano Dos Santos, F. L.; Cai, J.; Calina, D.; Camargos, P.; Cámera, L. A.; Cárdenas, R.; Cevik, M.; Chadwick, J.; Charan, J.; Chaurasia, A.; Ching, P. R.; Choudhari, S. G.; Chowdhury, E. K.; Chowdhury, F. R.; Chu, D.-T.; Chukwu, I. S.; Dadras, O.; Dagnaw, F. T.; Dai, X.; Das, S.; Dastiridou, A.; Debela, S. A.; Demisse, F. W.; Demissie, S.; Dereje, D.; Derese, M.; Desai, H. D.; Dessalegn, F. N.; Dessalegni, S. A. A.; Desye, B.; Dhaduk, K.; Dhimal, M.; Dhingra, S.; Diao, N.; Diaz, D.; Djalalinia, S.; Dodangeh, M.; Dongarwar, D.; Dora, B. T.; Dorostkar, F.; Dsouza, H. L.; Dubljanin, E.; Dunachie, S. J.; Durojaiye, O. C.; Edinur, H. A.; Ejigu, H. B.; Ekholuenetale, M.; Ekundayo, T. C.; El-Abid, H.; Elhadi, M.; Elmonem, M. A.; Emami, A.; Engelbert Bain, L.; Enyew, D. B.; Erkhembayar, R.;

Eshrati, B.; Etaee, F.; Fagbamigbe, A. F.; Falahi, S.; Fallahzadeh, A.; Faraon, E. J. A.; Fatehizadeh, A.; Fekadu, G.; Fernandes, J. C.; Ferrari, A.; Fetensa, G.; Filip, I.; Fischer, F.; Foroutan, M.; Gaal, P. A.; Gadanya, M. A.; Gaidhane, A. M.; Ganesan, B.; Gebrehiwot, M.; Ghanbari, R.; Ghasemi Nour, M.; Ghashghaee, A.; Gholamrezanezhad, A.; Gholizadeh, A.; Golechha, M.; Goleij, P.; Golinelli, D.; Goodridge, A.; Gunawardane, D. A.; Guo, Y.; Gupta, R. D.; Gupta, S.; Gupta, V. B.; Gupta, V. K.; Guta, A.; Habibzadeh, P.; Haddadi Avval, A.; Halwani, R.; Hanif, A.; Hannan, Md. A.; Harapan, H.; Hassan, S.; Hassankhani, H.; Hayat, K.; Heibati, B.; Heidari, G.; Heidari, M.; Heidari-Soureshjani, R.; Herteliu, C.; Heyi, D. Z.; Hezam, K.; Hoogar, P.; Horita, N.; Hossain, M. M.; Hosseinzadeh, M.; Hostiuc, M.; Hostiuc, S.; Hoveidamanesh, S.; Huang, J.; Hussain, S.; Hussein, N. R.; Ibitoye, S. E.; Ilesanmi, O. S.; Ilic, I. M.; Ilic, M. D.; Imam, M. T.; Immurana, M.; Inbaraj, L. R.; Iradukunda, A.; Ismail, N. E.; Iwu, C. C. D.; Iwu, C. J.; J, L. M.; Jakovljevic, M.; Jamshidi, E.; Javaheri, T.; Javanmardi, F.; Javidnia, J.; Jayapal, S. K.; Jayarajah, U.; Jebai, R.; Jha, R. P.; Joo, T.; Joseph, N.; Joukar, F.; Jozwiak, J. J.; Kacimi, S. E. O.; Kadashetti, V.; Kalankesh, L. R.; Kalhor, R.; Kamal, V. K.; Kandel, H.; Kapoor, N.; Karkhah, S.; Kassa, B. G.; Kassebaum, N. J.; Katoto, P. D.; Keykhaei, M.; Khajuria, H.; Khan, A.; Khan, I. A.; Khan, M.; Khan, M. N.; Khan, M. A.; Khatatbeh, M. M.; Khater, M. M.; Khayat Kashani, H. R.; Khubchandani, J.; Kim, H.; Kim, M. S.; Kimokoti, R. W.; Kissoon, N.; Kochhar, S.; Kompani, F.; Kosen, S.; Koul, P. A.; Koulmane Laxminarayana, S. L.; Krapp Lopez, F.; Krishan, K.; Krishnamoorthy, V.; Kulkarni, V.; Kumar, N.; Kurmi, O. P.; Kuttikkattu, A.; Kyu, H. H.; Lal, D. K.; Lám, J.; Landires, I.; Lasrado, S.; Lee, S.; Lenzi, J.; Lewycka, S.; Li, S.; Lim, S. S.; Liu, W.; Lodha, R.; Loftus, M. J.; Lohiya, A.; Lorenzovici, L.; Lotfi, M.; Mahmoodpoor, A.; Mahmoud, M. A.; Mahmoudi, R.; Majeed, A.; Majidpoor, J.; Makki, A.; Mamo, G. A.; Manla, Y.; Martorell, M.; Matei, C. N.; McManigal, B.; Mehrabi Nasab, E.; Mehrotra, R.; Melese, A.; Mendoza-Cano, O.; Menezes, R. G.; Mentis, A.-F. A.; Micha, G.; Michalek, I. M.; Micheletti Gomide Nogueira De Sá, A. C.; Milevska Kostova, N.; Mir, S. A.; Mirghafourvand, M.; Mirmoeeni, S.; Mirrakhimov, E. M.; Mirza-Aghazadeh-Attari, M.; Misganaw, A. S.; Misganaw, A.; Misra, S.; Mohammadi, E.; Mohammadi, M.; Mohammadian-Hafshejani, A.; Mohammed, S.; Mohan, S.; Mohseni, M.; Mokdad, A. H.; Momtazmanesh, S.; Monasta, L.; Moore, C. E.; Moradi, M.; Moradi Sarabi, M.; Morrison, S. D.; Motaghinejad, M.; Mousavi Isfahani, H.; Mousavi Khaneghah, A.; Mousavi-Aghdas, S. A.; Mubarik, S.; Mulita, F.; Mulu, G. B. B.; Munro, S. B.; Muthupandian, S.; Nair, T. S.; Naqvi, A. A.; Narang, H.; Natto, Z. S.; Naveed, M.; Nayak, B. P.; Naz, S.; Negoi, I.; Nejadghaderi, S. A.; Neupane Kandel, S.; Ngwa, C. H.; Niazi, R. K.; Nogueira De Sá, A. T.; Noroozi, N.; Nouraei, H.; Nowroozi, A.; Nuñez-Samudio, V.; Nutor, J. J.; Nzoputam, C. I.; Nzoputam, O. J.; Oancea, B.; Obaidur, R. M.; Ojha, V. A.; Okekunle, A. P.; Okonji, O. C.; Olagunju, A. T.; Olusanya, B. O.; Omar Bali, A.; Omer, E.; Otstavnov, N.; Oumer, B.; P A, M.; Padubidri, J. R.; Pakshir, K.; Palicz, T.; Pana, A.; Pardhan, S.; Paredes, J. L.; Parekh, U.; Park, E.-C.; Park, S.; Pathak, A.; Paudel, R.; Paudel, U.; Pawar, S.; Pazoki Toroudi, H.; Peng, M.; Pensato, U.; Pepito, V. C. F.; Pereira, M.; Peres, M. F. P.; Perico, N.; Petcu, I.-R.; Piracha, Z. Z.; Podder, I.; Pokhrel, N.; Poluru, R.; Postma, M. J.; Pourtaheri, N.; Prashant, A.; Qattea, I.; Rabiee, M.; Rabiee, N.; Radfar, A.; Raeghi, S.; Rafiei, S.; Raghav, P. R.; Rahbarnia, L.; Rahimi-Movaghar, V.; Rahman, M.; Rahman, M. A.; Rahmani, A. M.; Rahmanian, V.; Ram, P.; Ranjha, M. M. A. N.; Rao, S. J.; Rashidi, M.-M.; Rasul, A.; Ratan, Z. A.; Rawaf, S.; Rawassizadeh, R.; Razeghinia, M. S.; Redwan, E. M. M.; Regasa, M. T.; Remuzzi, G.; Reta, M. A.; Rezaei, N.; Rezapour, A.; Riad, A.; Ripon, R. K.; Rudd, K. E.; Saddik, B.; Sadeghian, S.; Saeed, U.; Safaei, M.; Safary, A.; Safi, S. Z.; Sahebazzamani, M.; Sahebkar, A.; Sahoo, H.; Salahi, S.; Salahi, S.; Salari, H.; Salehi, S.; Samadi Kafil, H.; Samy, A. M.; Sanadgol, N.; Sankararaman, S.; Sanmarchi, F.; Sathian, B.; Sawhney, M.; Saya, G. K.; Senthilkumaran, S.; Seylani, A.; Shah, P. A.; Shaikh, M. A.; Shaker, E.; Shakhmardanov, M. Z.; Sharew, M. M.; Sharifi-Razavi, A.; Sharma, P.; Sheikhi, R. A.; Sheikhy, A.; Shetty, P. H.; Shigematsu, M.; Shin, J. I.; Shirzad-Aski, H.; Shivakumar, K. M.; Shobeiri, P.; Shorofi, S. A.; Shrestha, S.; Sibhat, M. M.; Sidemo, N. B.; Sikder, M. K.; Silva, L. M. L. R.; Singh, J. A.; Singh, P.; Singh, S.; Siraj, M. S.; Siwal, S. S.; Skryabin, V. Y.; Skryabina, A. A.; Socea, B.; Solomon, D. D.; Song, Y.; Sreeramareddy, C. T.; Suleman, M.; Suliankatchi Abdulkader, R.; Sultana, S.; Szócska, M.; Tabatabaeizadeh, S.-A.; Tabish, M.; Taheri, M.; Taki, E.; Tan, K.-K.; Tandukar, S.; Tat, N. Y.; Tat, V. Y.; Tefera, B. N.; Tefera, Y. M.; Temesgen, G.; Temsah, M.-H.; Tharwat, S.; Thiyagarajan, A.; Tleyjeh, I. I.; Troeger, C. E.;

Umapathi, K. K.; Upadhyay, E.; Valadan Tahbaz, S.; Valdez, P. R.; Van Den Eynde, J.; Van Doorn, H. R.; Vaziri, S.; Verras, G.-I.; Viswanathan, H.; Vo, B.; Waris, A.; Wassie, G. T.; Wickramasinghe, N. D.; Yaghoubi, S.; Yahya, G. A. T. Y.; Yahyazadeh Jabbari, S. H.; Yigit, A.; Yiğit, V.; Yon, D. K.; Yonemoto, N.; Zahir, M.; Zaman, B. A.; Zaman, S. B.; Zangiabadian, M.; Zare, I.; Zastrozhin, M. S.; Zhang, Z.-J.; Zheng, P.; Zhong, C.; Zoladl, M.; Zumla, A.; Hay, S. I.; Dolecek, C.; Sartorius, B.; Murray, C. J. L.; Naghavi, M. Global Mortality Associated with 33 Bacterial Pathogens in 2019: A Systematic Analysis for the Global Burden of Disease Study 2019. *The Lancet* **2022**, *400*, 2221–2248.

(289) Maglangit, F.; Yu, Y.; Deng, H. Bacterial Pathogens: Threat or Treat (a Review on Bioactive Natural Products from Bacterial Pathogens). *Nat. Prod. Rep.* **2021**, *38*, 782–821.

(290) Bosch, F.; Rosich, L. The Contributions of Paul Ehrlich to Pharmacology: A Tribute on the Occasion of the Centenary of His Nobel Prize. *Pharmacology* **2008**, *82*, 171–179.

(291) Sodhi, R. K. Metal Complexes in Medicine: An Overview and Update from Drug Design Perspective. *CTOIJ* **2019**, *14*.

(292) Mjos, K. D.; Orvig, C. Metallodrugs in Medicinal Inorganic Chemistry. *Chem. Rev.* **2014**, *114*, 4540–4563.

(293) Ludwig, B. S.; Correia, J. D. G.; Kühn, F. E. Ferrocene Derivatives as Anti-Infective Agents. *Coordination Chemistry Reviews* **2019**, *396*, 22–48.

(294) Patra, M.; Gasser, G. The Medicinal Chemistry of Ferrocene and Its Derivatives. *Nat Rev Chem* **2017**, *1*, 0066.

(295) Nandanwar, S. K.; Kim, H. J. Anticancer and Antibacterial Activity of Transition Metal Complexes. *ChemistrySelect* **2019**, *4*, 1706–1721.

(296) Guo, Z.; Sadler, P. J. Metals in Medicine. *Angew. Chem. Int. Ed.* **1999**, *38*, 1512–1531.

(297) Claudel, M.; Schwarte, J. V.; Fromm, K. M. New Antimicrobial Strategies Based on Metal Complexes. *Chemistry* **2020**, *2*, 849–899.

(298) Nasiri Sovari, S.; Zobi, F. Recent Studies on the Antimicrobial Activity of Transition Metal Complexes of Groups 6–12. *Chemistry* **2020**, *2*, 418–452.

(299) Hess, J. Rational Approaches towards Inorganic and Organometallic Antibacterials. *Biological Chemistry* **2022**, *403*, 363–375.

(300) Biegański, P.; Szczupak, Ł.; Arruebo, M.; Kowalski, K. Brief Survey on Organometalated Antibacterial Drugs and Metal-Based Materials with Antibacterial Activity. *RSC Chem. Biol.* **2021**, *2*, 368–386.

(301) Frei, A.; Verderosa, A. D.; Elliott, A. G.; Zuegg, J.; Blaskovich, M. A. T. Metals to Combat Antimicrobial Resistance. *Nat Rev Chem* **2023**, *7*, 202–224.

(302) Rakshit, T.; Haldar, A.; Jana, S.; Raha, S.; Saha, R.; Mandal, D. A Brief Review on the Antimicrobial Activity of Transition Metal Complexes with N,O Donor Chelating Ligand. *Results in Chemistry* **2023**, *6*, 101224.

(303) Singh, A.; Barman, P. Recent Advances in Schiff Base Ruthenium Metal Complexes: Synthesis and Applications. *Top Curr Chem (Z)* **2021**, *379*, 29.

(304) Soroceanu, A.; Bargan, A. Advanced and Biomedical Applications of Schiff-Base Ligands and Their Metal Complexes: A Review. *Crystals* **2022**, *12*, 1436.

(305) Boulechfar, C.; Ferkous, H.; Delimi, A.; Djedouani, A.; Kahlouche, A.; Boublia, A.; Darwish, A. S.; Lemaoui, T.; Verma, R.; Benguerba, Y. Schiff Bases and Their Metal Complexes: A Review on the History, Synthesis, and Applications. *Inorganic Chemistry Communications* **2023**, *150*, 110451.

(306) Alreja, P.; Kaur, N. Probing Anion and Cation with Novel Salicylidene Schiff Base Receptor Appended with 1, 10-Phenanthroline: Mimicking INHIBIT Molecular Logic Gate. *Inorganica Chimica Acta* **2018**, *480*, 127–131.

(307) Wesley Jeevadason, A.; Kalidasa Murugavel, K.; Neelakantan, M. A. Review on Schiff Bases and Their Metal Complexes as Organic Photovoltaic Materials. *Renewable and Sustainable Energy Reviews* **2014**, *36*, 220–227.

(308) Zhang, J.; Xu, L.; Wong, W.-Y. Energy Materials Based on Metal Schiff Base Complexes. *Coordination Chemistry Reviews* **2018**, *355*, 180–198.

(309) Verma, S.; Chandra, S.; Dev, U.; Joshi, N. Synthesis, Spectral and Biological Studies of Nitrogen–Sulphur Donor Macrocyclic Ligands and Their Transition Metals Complexes. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* **2009**, *74*, 370–374.
(310) Wantulok, J.; Szala, M.; Quinto, A.; Nycz, J. E.; Giannarelli, S.; Sokolová, R.; Książek, M.; Kusz, J. Synthesis, Electrochemical and Spectroscopic Characterization of Selected Quinolinecarbaldehydes and Their Schiff Base Derivatives. *Molecules* **2020**, *25*, 2053.
(311) Tyagi, A.; Purohit, S.; Oswal, P.; Rawat, S.; Negi, V.; Singh, A. K.; Kumar, A. Nucleophilic Substitution Reaction as an Important Tool in the Synthetic Protocol for Selenium Donor Containing Schiff Bases: Applications of Metal Complexes in Homogeneous Catalysis. *New J. Chem.* **2023**, *47*, 12511–12535.
(312) More, M. S.; Joshi, P. G.; Mishra, Y. K.; Khanna, P. K. Metal Complexes Driven from Schiff Bases and Semicarbazones for Biomedical and Allied Applications: A Review. *Materials Today Chemistry* **2019**, *14*, 100195.
(313) Chohan, Z. H.; Sumrra, S. H.; Youssoufi, M. H.; Hadda, T. B. Metal Based Biologically Active Compounds: Design, Synthesis, and Antibacterial/Antifungal/Cytotoxic Properties of Triazole-Derived Schiff Bases and Their Oxovanadium(IV) Complexes. *European Journal of Medicinal Chemistry* **2010**, *45*, 2739–2747.
(314) Sun, Y.; Lu, Y.; Bian, M.; Yang, Z.; Ma, X.; Liu, W. Pt(II) and Au(III) Complexes Containing Schiff-Base Ligands: A Promising Source for Antitumor Treatment. *European Journal of Medicinal Chemistry* **2021**, *211*, 113098.
(315) Hassan, A. S.; Awad, H. M.; Magd-El-Din, A. A.; Hafez, T. S. Synthesis and in Vitro Antitumor Evaluation of Novel Schiff Bases. *Med Chem Res* **2018**, *27*, 915–927.
(316) Cheng, L.-X.; Tang, J.-J.; Luo, H.; Jin, X.-L.; Dai, F.; Yang, J.; Qian, Y.-P.; Li, X.-Z.; Zhou, B. Antioxidant and Antiproliferative Activities of Hydroxyl-Substituted Schiff Bases. *Bioorganic & Medicinal Chemistry Letters* **2010**, *20*, 2417–2420.
(317) Schatzschneider, U.; Metzler-Nolte, N. New Principles in Medicinal Organometallic Chemistry. *Angew Chem Int Ed* **2006**, *45*, 1504–1507.
(318) Gasser, G.; Metzler-Nolte, N. The Potential of Organometallic Complexes in Medicinal Chemistry. *Current Opinion in Chemical Biology* **2012**, *16*, 84–91.
(319) Smitten, K. L.; Fairbanks, S. D.; Robertson, C. C.; Bernardino De La Serna, J.; Foster, S. J.; Thomas, J. A. Ruthenium Based Antimicrobial Theranostics – Using Nanoscopy to Identify Therapeutic Targets and Resistance Mechanisms in *Staphylococcus Aureus*. *Chem. Sci.* **2020**, *11*, 70–79.
(320) Lee, L. C.-C.; Leung, K.-K.; Lo, K. K.-W. Recent Development of Luminescent Rhenium(I) Tricarbonyl Polypyridine Complexes as Cellular Imaging Reagents, Anticancer Drugs, and Antibacterial Agents. *Dalton Trans.* **2017**, *46*, 16357–16380.
(321) Miller, R. G.; Vázquez-Hernández, M.; Prochnow, P.; Bandow, J. E.; Metzler-Nolte, N. A CuAAC Click Approach for the Introduction of Bidentate Metal Complexes to a Sulfanilamide-Derived Antibiotic Fragment. *Inorg. Chem.* **2019**, *58*, 9404–9413.
(322) Mandal, A.; Rai, R.; Saha, S.; Kushwaha, R.; Wei, L.; Gogoi, H.; Mandal, A. A.; Yadav, A. K.; Huang, H.; Dutta, A.; Dhar, P.; Banerjee, S. Polypyridyl-Based Co(iii) Complexes of Vitamin B_6 Schiff Base for Photoactivated Antibacterial Therapy. *Dalton Trans.* **2023**, *52*, 17562–17572.
(323) Wang, Z.-F.; Wei, Q.-C.; Li, J.-X.; Zhou, Z.; Zhang, S.-H. A New Class of Nickel(ii) Oxyquinoline–Bipyridine Complexes as Potent Anticancer Agents Induces Apoptosis and Autophagy in A549/DDP Tumor Cells through Mitophagy Pathways. *Dalton Trans.* **2022**, *51*, 7154–7163.
(324) Vinagreiro, C. S.; Lopes, R.; Royo, B.; Da Silva, G. J.; Pereira, M. M. Synthesis of Iron(II)–N-Heterocyclic Carbene Complexes: Paving the Way for a New Class of Antibiotics. *Molecules* **2020**, *25*, 2917.
(325) Azam, M.; Al-Resayes, S.; Wabaidur, S.; Altaf, M.; Chaurasia, B.; Alam, M.; Shukla, S.; Gaur, P.; Albaqami, N.; Islam, M.; Park, S. Synthesis, Structural Characterization and Antimicrobial Activity of Cu(II) and Fe(III) Complexes Incorporating Azo-Azomethine Ligand. *Molecules* **2018**, *23*, 813.

(326) Scaccaglia, M.; Birbaumer M. P.; Pinelli, S.; Pelosi, G.; Frei A. Discovery of antibacterial manganese(I) tricarbonyl complexes through combinatorial chemistry *Chem. Sci.,* **2024,** *15*, 3907.
(327) Pechancová, R.; Pluháček, T.; Milde, D. Recent Advances in Chromium Speciation in Biological Samples. *Spectrochimica Acta Part B: Atomic Spectroscopy* **2019**, *152*, 109–122.
(328) Hossini, H.; Shafie, B.; Niri, A. D.; Nazari, M.; Esfahlan, A. J.; Ahmadpour, M.; Nazmara, Z.; Ahmadimanesh, M.; Makhdoumi, P.; Mirzaei, N.; Hoseinzadeh, E. A Comprehensive Review on Human Health Effects of Chromium: Insights on Induced Toxicity. *Environ Sci Pollut Res* **2022**, *29*,70686–70705.
(329) (a) Peng, M.; Yang, X. Controlling Diabetes by Chromium Complexes: The Role of the Ligands. *Journal of Inorganic Biochemistry* **2015**, *146*, 97–103.
(330) Bartholomäus, R.; Irwin, J. A.; Shi, L.; Smith, S. M.; Levina, A.; Lay, P. A. Isolation, Characterization, and Nuclease Activity of Biologically Relevant Chromium(V) Complexes with Monosaccharides and Model Diols. Likely Intermediates in Chromium-Induced Cancers. *Inorg. Chem.* **2013**, *52*, 4282–4292.
(331) Patra, M.; Merz, K.; Metzler-Nolte, N. Planar Chiral (η^6-Arene)$Cr(CO)_3$ Containing Carboxylic Acid Derivatives: Synthesis and Use in the Preparation of Organometallic Analogues of the Antibiotic Platensimycin. *Dalton Trans.* **2012**, *41*,112–117.
(332) Patra, M.; Ingram, K.; Pierroz, V.; Ferrari, S.; Spingler, B.; Gasser, R. B.; Keiser, J.; Gasser, G. [(η^6-Praziquantel)$Cr(CO)_3$] Derivatives with Remarkable In Vitro Anti-schistosomal Activity. *Chemistry A European J* **2013**, *19*, 2232–2235.
(333) Fattah, M. S.; Essa, S. M. Analytical and Biological Evaluation of Chromium Complex with Organic Detector NTADBrP: Stability, Calibration, and Inhibition Studies. In *RAiSE-2023*; MDPI, 2024, 227.
(334) Murcia, R.; Leal, S.; Roa, M.; Nagles, E.; Muñoz-Castro, A.; Hurtado, J. Development of Antibacterial and Antifungal Triazole Chromium (III) and Cobalt (II) Complexes: Synthesis and Biological Activity Evaluations. *Molecules* **2018**, *23*, 2013.
(335) Patra, M.; Gasser, G.; Pinto, A.; Merz, K.; Ott, I.; Bandow, J. E.; Metzler-Nolte, N. Synthesis and Biological Evaluation of Chromium Bioorganometallics Based on the Antibiotic Platensimycin Lead Structure. *ChemMedChem* **2009**, *4* , 1930–1938.
(336) (a) Casarrubios, L.; de la Torre, M. C.; Sierra, M. A. The "Click" Reaction Involving Metal Azides, Metal Alkynes, or Both: An Exploration into Multimetal Structures. *Chemistry A European J* **2013**, *19*, 3534–3541.
(337) Pandey, O. P.; Sengupta, S. K.; Tripathi, S. C. Thio-Schiff Base Derivatives of Chromium and Molybdenum Hexacarbonyls. *Synthesis and Reactivity in Inorganic and Metal-Organic Chemistry* **1984**, *14*, 827–836.
(338) Tripathi, S. C.; Srivastava, S. C.; Shrimal, A. K.; Singh, O. P. Schiff-Base Derivatives of Molybdenum Carbonyl. *Transition Met Chem* **1984**, *9*, 478–482.
(339) Ali, O. A. M.; El-Medani, S. M.; Ahmed, D. A.; Nassar, D. A. Metal Carbonyl Complexes with Schiff Bases Derived from 2-Pyridinecarboxaldehyde: Syntheses, Spectral, Catalytic Activity and Antimicrobial Activity Studies. *Journal of Molecular Structure* **2014**, *1074*, 713–722.
(340) Vlasiou, M. C.; Pafiti, K. S. Chromium Coordination Compounds with Antimicrobial Activity: Synthetic Routes, Structural Characteristics, and Antibacterial Activity. *TOMCJ* **2020**, *14*, 1–25. (f) Tripathi, S. C.; Srivastava, S. C.; Shrimal, A. K.; Singh, O. P. Schiff Base Derivatives of Chromium Carbonyl. *Inorganica Chimica Acta* **1985**, *98*, 19–23.
(341) Perera, S. D.; Fernandez-Sanchez, J. J.; Shaw, B. L. Activation of C–X (X=Cl or Br) Bonds in 2-Halobenzaldehydes as Their 2-Pyridylhydrazone Derivatives: Oxidative Addition to Tungsten(0) to Give Aryl–Tungsten(II) Complexes. *Inorganica Chimica Acta* **2001**, *325*, 175–178.
(342) Calderazzo, F.; Floriani, C.; Henzi, R.; L'Eplattenier, F. Reactions of Some Metal Carbonyls with Chelating Compounds Containing Active Protons, Especially Schiff's Bases. *J. Chem. Soc., A* **1969**, 1378.
(343) Himmelbauer, D.; Stöger, B.; Veiros, L. F.; Pignitter, M.; Kirchner, K. Cr(II) and Cr(I) PCP Pincer Complexes: Synthesis, Structure, and Catalytic Reactivity. *Organometallics* **2019**, *38*, 4669–4678.

(344) (a) Sinha, N.; Wegeberg, C.; Häussinger, D.; Prescimone, A.; Wenger, O. S. Photoredox-Active Cr(0) Luminophores Featuring Photophysical Properties Competitive with Ru(II) and Os(II) Complexes. *Nat. Chem.* **2023**, *15* , 1730–1736.
(345) Wallace, A. C.; Laskowski, R. A.; Thornton, J. M. LIGPLOT: A Program to Generate Schematic Diagrams of Protein-Ligand Interactions. *Protein Eng Des Sel* **1995**, *8*, 127–134.
(346) MacPherson, D. S.; Fung, K.; Cook, B. E.; Francesconi, L. C.; Zeglis, B. M. A Brief Overview of Metal Complexes as Nuclear Imaging Agents. *Dalton Trans.* **2019**, *48*, 14547–14565.
(347) Johnstone, T. C.; Suntharalingam, K.; Lippard, S. J. The Next Generation of Platinum Drugs: Targeted Pt(II) Agents, Nanoparticle Delivery, and Pt(IV) Prodrugs. *Chem. Rev.* **2016**, *116* , 3436–3486.
(348) AbdelKhalek, A.; Abutaleb, N. S.; Elmagarmid, K. A.; Seleem, M. N. Repurposing Auranofin as an Intestinal Decolonizing Agent for Vancomycin-Resistant Enterococci. *Sci Rep* **2018**, *8*, 8353.
(349) Gerasimchuk, N.; Pinks, K.; Salpadoru, T.; Cotton, K.; Michka, O.; Patrauchan, M. A.; Wozniak, K. L. Non-Antibiotic Antimony-Based Antimicrobials. *Molecules* **2022**, *27*, 7171.
(350) Carpenter, E. P.; Corbett, A.; Thomson, H.; Adacha, J.; Jensen, K.; Bergeron, J.; Kasampalidis, I.; Exley, R.; Winterbotham, M.; Tang, C.; Baldwin, G. S.; Freemont, P. AP Endonuclease Paralogues with Distinct Activities in DNA Repair and Bacterial Pathogenesis. *EMBO J* **2007**, *26*, 1363–1372.
(351) Mol, C. D.; Hosfield, D. J.; Tainer, J. A. Abasic Site Recognition by Two Apurinic/Apyrimidinic Endonuclease Families in DNA Base Excision Repair: The 3′ Ends Justify the Means. *Mutation Research/DNA Repair* **2000**, *460*, 211–229.
(352) Fasnacht, M.; Polacek, N. Oxidative Stress in Bacteria and the Central Dogma of Molecular Biology. *Front. Mol. Biosci.* **2021**, *8*, 671037.
(353) Clarke, R. S.; Ha, K. P.; Edwards, A. M. Multiple Classes of Bactericidal Antibiotics Cause DNA Double Strand Breaks in *Staphylococcus Aureus*. March 6, 2021.
(354) Ischenko, A. A.; Saparbaev, M. K. Alternative Nucleotide Incision Repair Pathway for Oxidative DNA Damage. *Nature* **2002**, *415*, 183–187.
(355) Gohil, D.; Sarker, A. H.; Roy, R. Base Excision Repair: Mechanisms and Impact in Biology, Disease, and Medicine. *IJMS* **2023**, *24*, 14186.
(356) Casida, M. E.; Jamorski, C.; Casida, K. C.; Salahub, D. R. Molecular Excitation Energies to High-Lying Bound States from Time-Dependent Density-Functional Response Theory: Characterization and Correction of the Time-Dependent Local Density Approximation Ionization Threshold. *The Journal of Chemical Physics* **1998**, *108*, 4439–4449.
(357) Stratmann, R. E.; Scuseria, G. E.; Frisch, M. J. An Efficient Implementation of Time-Dependent Density-Functional Theory for the Calculation of Excitation Energies of Large Molecules. *The Journal of Chemical Physics* **1998**, *109*, 8218–8224.
(358) O'boyle, N. M.; Tenderholt, A. L.; Langner, K. M. Cclib: A Library for Package-independent Computational Chemistry Algorithms. *J Comput Chem* **2008**, *29*, 839–845.
(359) Krasnoshchekov, S. V.; Efremov, I. M.; Polyakov, I. V.; Millionshchikov, D. V. Systematic *Ab Initio* Calculation of Spectroscopic Constants for *A* -Reduced Rotational Effective Hamiltonians of Asymmetric Top Molecules Using Normal Ordering of Cylindrical Angular Momentum Operators. *The Journal of Chemical Physics* **2024**, *161*, 234105.
(360) Zhurko, G. G. A.; Zhurko, D. A. ChemCraft 1.5, Plimus, San Diago, CA. Available at:https://www.chemcraftprog.com/.
(361) Turgimbayeva, A.; Zein, U.; Zharkov, D. O.; Ramankulov, Y.; Saparbaev, M.; Abeldenov, S. Cloning and Characterization of the Major AP Endonuclease from Staphylococcus Aureus. *DNA Repair* **2022**, *119*, 103390.
(362) Garcin, E. D.; Hosfield, D. J.; Desai, S. A.; Haas, B. J.; Björas, M.; Cunningham, R. P.; Tainer, J. A. DNA Apurinic-Apyrimidinic Site Binding and Excision by Endonuclease IV. *Nat Struct Mol Biol* **2008**, *15*, 515–522.
(363) Beargie, R. A.; Bracken, E. C.; Riley, H. D. Micromethod (Spot-Plate) Determination of In Vitro Antibiotic Susceptibility. *Appl Microbiol* **1965**, *13*, 279–280.

(364) Zhu, F.; Shi, Z.; Qin, C.; Tao, L.; Liu, X.; Xu, F.; Zhang, L.; Song, Y.; Liu, X.; Zhang, J.; Han, B.; Zhang, P.; Chen, Y. Therapeutic Target Database Update 2012: A Resource for Facilitating Target-Oriented Drug Discovery. *Nucleic Acids Research* **2012**, *40*, D1128–D1136.
(365) Trott, O.; Olson, A. J. AutoDock Vina: Improving the Speed and Accuracy of Docking with a New Scoring Function, Efficient Optimization, and Multithreading. *J Comput Chem* **2010**, *31*, 455–461.
(366) Morris, G. M.; Huey, R.; Lindstrom, W.; Sanner, M. F.; Belew, R. K.; Goodsell, D. S.; Olson, A. J. AutoDock4 and AutoDockTools4: Automated Docking with Selective Receptor Flexibility. *J Comput Chem* **2009**, *30*, 2785–2791.
(367) Wallace, A. C.; Laskowski, R. A.; Thornton, J. M. LIGPLOT: A Program to Generate Schematic Diagrams of Protein-Ligand Interactions. *Protein Eng Des Sel* **1995**, *8*, 127–134.
(368) Jiménez, J.; Škalič, M.; Martínez-Rosell, G.; De Fabritiis, G. K_{DEEP}: Protein–Ligand Absolute Binding Affinity Prediction via 3D-Convolutional Neural Networks. *J. Chem. Inf. Model.* **2018**, *58*, 287–296.

…